Souhegan River
Protected Instream Flow Report

DRAFT

University of New Hampshire
University of Massachusetts
Normandeau Associates, Inc.

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Executive Summary

The instream protected users, outstanding characteristics, and resources (IPUOCR) of the Souhegan River were identified in a previous report. This report develops the protected instream flow for the IPUOCR. For each IPUOCR, their location, description, instream flow evaluation method, and instream flow recommendations are presented. Given the river length and the fact that flow generally increases in the downstream direction, the Souhegan River was subdivided into seven sections. For the human-related IPUOCR, the following table summarizes their recommended protected instream flow (PISF).

PISFs for selected IPUOCRs							
IPUOCR	**Reach**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Recreation	150 cfs; 4.0 cfsm		Use is not dependent on Souhegan River flow.				
Fishing	Use is dependent on Souhegan River flow only to the extent that it protects the fishery resource. Fish and aquatic habitat apply.						
Hydropower	~20 cfs; ~0.7 cfsm	No users	~42.2 cfs; ~0.44 cfsm	No users			
Pollution Abatement	2.4 cfs; <0.1 cfsm			9.4 cfs; <0.1cfsm			
Water Supply	Use is not dependent on Souhegan River flow						

For ecosystems and aquatic life, the instream flows are not as simple because these flows are designated by species and for different times of the year. It should be recognized that the flow of water is but one of many characteristics of the Souhegan River that meets the needs of users and the ecosystems. However it must be underscored that the flow of water alone does not guarantee that these needs are met: just as important is the water quality associated with that water. As this effort moves into the next stages of the development of a water management plan, the notes found in this report that address water quality (such as temperature) may offer more promising gains in meeting objectives than just insuring that more water flows in the river.

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Introduction

This Protected Instream Flow report represents the completion of Task 5 of the work schedule defined for the Instream Flow Studies and Water Management Plan for the Souhegan River Designated Reach. This report combines previous information describing the flow-dependent instream protected uses, outstanding characteristics, and resources (IPUOCRs) with estimates of the flow needs for each of these IPUOCRs. IPUOCR categories include: recreation; fishing; pubic water supply; pollution abatement; hydroelectric energy production; fish and wildlife habitat; aquatic and fish life maintenance and enhancement; rare, threatened and endangered species (RTE): fish, wildlife, vegetation and natural/ecological communities; and environmental/fish habitat. For each of these flow-dependent IPUOCRs, their location and protection goals are delineated as well as the methods used to determine these goals.

The first part of this report describes each IPUOCR and their respective flow goal. The second part of this report looks at these goals in light of the existing system hydrology and withdrawals in order to determine if and when goals are not met.

To get to the final form of this report, it will first be presented to the Technical Review Committee and then the general public. Comments and questions on the report and its findings will be addressed and synthesized into the final version of this report.

Part 1. Locations and the Protection Goals for IPUOCR Entities

I.) Recreation

The Appalachian Mountain Club (AMC) River Guide (AMC, 2002) describes the Souhegan River as good intermediate whitewater in the upper portions (Greenville to Wilton) with a mixture of flatwater, quickwater, and short rapids sections in the lower portions from Milford to the Merrimack River. With the exception of the reach from the Turkey Hill Bridge to Merrimack, the river is characterized as boatable in high water. High water conditions most commonly occur in the spring with snowmelt (April) but may occur on occasion in response to a large rainstorms during summer or fall. Such an event occurred on October 7-9, 2005. Eight to ten inches of rain fell on the watershed during this period, increasing flows in the river from 27 cfs (0.16 cfsm) at the Merrimack gaging station on October 8 at 00:15 to a peak of 1,190 cfs (6.96 cfsm) on October 9 between 19:15 and 21:30.

Figure 1. View looking upstream from Route 31 Bridge, October 10, 2005.

A qualitative recreational survey was conducted between 12:00 and 15:00 on October 10, 2005. At 12:00 on October 10, flow had declined to 815 cfs (4.77 cfsm) and by 15:00 had declined further to 761 cfs (4.45 cfsm), Figure 1. A total of nine boaters were interviewed at the Route 31 River crossing in Wilton near the Greenville town line (Figure 2). Several other boaters were present, but were not interviewed. Eight of the boaters were kayakers while one was a whitewater canoeist. The interviews were informal, but the following information was solicited:

How often do you boat on the Souhegan?

From where did you travel?

How do you monitor flow conditions on the Souhegan River for this location?

Which reaches of the river do you run?

What is the best flow range to run?

What is the minimum flow you would consider running?

Can we contact you for a follow up?

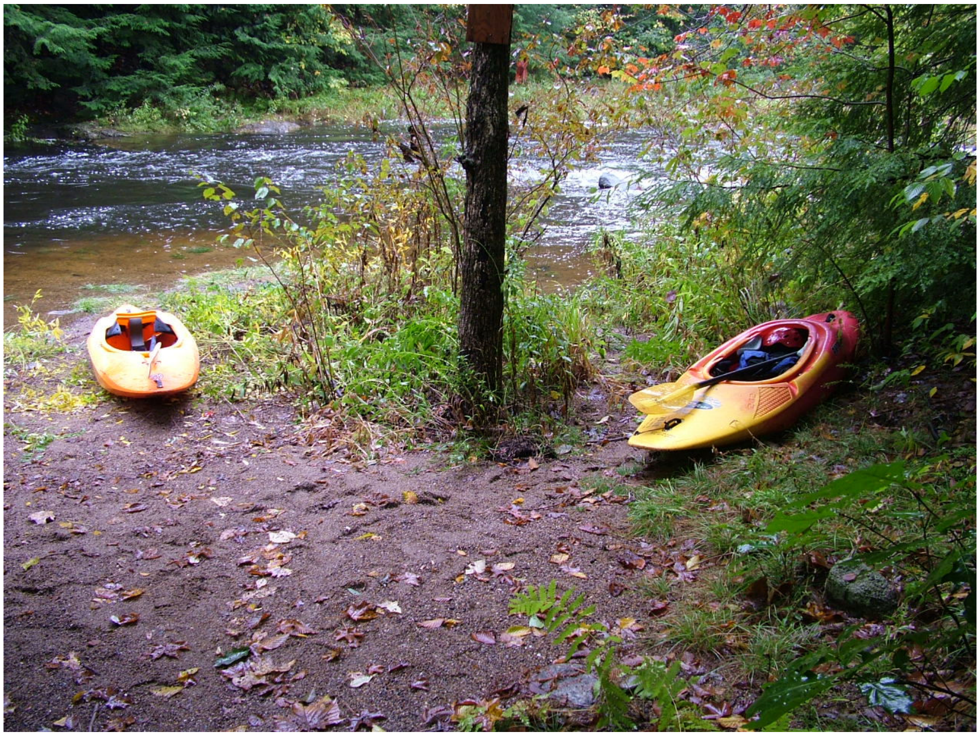


Figure 2. Access point at Route 31 Bridge, October 10, 2005.

The individuals interviewed typically boated the river three to four times per year, although one respondent had not boated the Souhegan in 25 years and another ran the river 12 times a year. Many of those interviewed had been boating on the Souhegan for many years and had considerable experience on the river over a broad range of flow conditions.

The primary boating season was the spring during and after snowmelt and during other times of the year in response to major runoff events triggered by slow moving fronts or hurricane remnants. Most of the boaters had not been on the Souhegan since the past spring. Table 1 summarizes the likelihood of finding suitable conditions for whitewater boating on the Souhegan by month. This table was constructed by American Whitewater from several years of flow records.

All of the boaters interviewed were from southern New Hampshire and northern Massachusetts with the furthest away traveling from Lexington, MA. The Souhegan can probably be categorized as a local to regional boating destination.

Boaters monitored the flow conditions on the Souhegan with a variety of sources including, word of mouth, the USGS gage in Merrimack, two hand-painted gages on the upper reaches of the Souhegan, or a general knowledge of how the Souhegan compares to flows in other gaged rivers. Boaters also obtained information on conditions from the Merrimack Valley Paddlers webpage www.mvp.org , the American Whitewater Association webpage www.americanwhitewater.org and the Appalachian Mountain Club paddlers web page www.nhamcpaddlers.org A general frustration at the discontinuation of the gage on Stoney

Brook was voiced (since conditions there mirror the upper Souhegan better than the Merrimack gage) and a suggestion for a telemetered gage in the upper portion of the Souhegan was offered. It was generally believed that although there was a relationship between the reading at the USGS gage and the flows on the upper river, it was not always consistent particularly when flows were changing rapidly. Once the boaters reach the river, the hand painted gages are the primary sources of flow information. One gage is on the downstream end of the concrete wall at the shorebank fishing access site in Greenville (Figure 3) and another is downstream of the Route 31 Bridge and is visible from the bridge. The gages are marked in 0.5 foot increments, although there does not seem to be any direct relationship between the two gages.

Table 1. Estimated chance (%) of finding the upper Souhegan runable.

Month	% Chance	Comment
January	5%	Usually frozen
February	10%	Usually frozen
March	40%	
April	65%	Opens up about mid-month
May	20%	Best chance in early April
June	8%	Best chance in early May
July	5%	
August	5%	Just a trickle
September	10%	Remains of Tropical storms
October	15%	
November	20%	Fall rains, dormant trees
December	20%	Freeze near Christmas

Source: http://www.americanwhitewater.org/rivers/id/1185

At the time of the survey, the upper gage was at 1.5 feet while the Route 31 Bridge gage was at 1.4 feet. At the upper gage, boating is possible at gage readings of 1.0 feet and above although 1.5 feet was considered the minimum for some respondents. At a gage height of 2 feet, the conditions are considered good, at 2.5 even better (Table 2). At a gage height of 3 feet one respondent noted that the water was in the woods and he would not run it. Another responded that there was no upper limit. It is worth noting that the gage reading was reported to be 2 feet on October 9, 2005 when the flow at the USGS gage downstream in Merrimack was 1,190 cfs (6.96 cfsm). Several boaters agreed that the minimum flow for boating was around 700 cfs (4.09 cfsm) at the USGS gage and the optimal was around 1,200 cfs (7.02 cfsm). Many stated that they would not consider running the river at flows lower than those at the time of the interview (760-815 cfs at the USGS gage). Two boaters related conditions to the gage height at the USGS gage indicating that a gage height of 4 feet is marginal, the height the day of the interview (October 10) of 4.7 feet was acceptable while a height of 6 feet at the USGS gage was too high.

Figure 3. Hand Painted Gage at Shore bank Fishing Access in Greenville.

The majority of the boaters on the river on October 10, 2005 were running the “steep” section of the upper river from the shorebank fishing access in Greenville to the Route 31 bridge near the Wilton/Greenville town line. Two boaters were running the river down to the Route 101 bridge in Wilton. It appeared from the group interviewed that the upper section of the river was the most popular for whitewater enthusiasts (Figure 4).

Whitewater boating on the Souhegan River is clearly a flow dependent resource (Figure 4). Successful running of the river requires flows above the average flow (Merrimack gage flow of 282 cfs or 1.65 cfsm). These flows are not expected to be influenced by many of the measures proposed as a part of the Water Management Plan (WMP). Should the WMP recommend measures such as flood skimming to put water into storage, the impact of these activities on whitewater boating will be evaluated further and more quantitatively. Metrics such as those presented in Table 1 will be used to quantify the potential impact of any proposed water management activities on this resource.

Table 2. Runability of Upper Souhegan based on two hand-painted gages on upper river (Greenville and Route 31 Bridge).

Greenville Put-in (reading in ft)	Route 31 Bridge (reading in ft)	Runability
0.8	1.3	Minimum play
0.9	1.4	level at bridge hole
1.0	1.5	Minimum level most people like
1.2	1.5	
1.4	1.6	Good surfing at ledges
1.7	1.7	Medium low
1.9	1.8	
2.1	1.9	Medium
2.25	2.0	Medium high
2.4	2.1	High

Note: Beyond 2.1 feet at the bridge, the gage is not reliable because of the velocity of the river.

Source: http://www.americanwhitewater.org/rivers/id/1185

Figure 4. Boaters Downstream of Route 31 Bridge, October 10, 2005.

II.) Fishing

The Souhegan River is a popular destination for recreational fishing. It is easily accessible by road, can be waded or fished from shore in most locations, and provides a variety of habitats for anglers to fish. Native fish species that may be targeted by anglers include:

- Atlantic salmon
- Brook trout
- Pumpkinseed
- Redbreast sunfish
- Yellow perch

Additionally, a number of species have been introduced and are now established within the Souhegan that are of interest to fisherman include:

- Largemouth bass
- Smallmouth bass
- Bluegill
- Black crappie

However, the majority of fishing on the Souhegan is aimed at stocked trout species. The New Hampshire Fish and Game Department regularly stocks trout into the Amherst, Greenville, Merrimack, Milford, New Ipswich, and Wilton sections of the Souhegan River. Brown and rainbow trout, two non-native species, along with native brook trout are stocked regularly. Table 3 presents the 2004 stocking data for the Souhegan, which were obtained from the New Hampshire Fish and Game Department's website (www.wildlife.state.nh.us/Fishing/fishing.htm).

Recreational fishing on the Souhegan River is a flow dependent resource. The protected instream flows that are required to maintain the environmental and fish habitat resource are those that will be adequate to preserve recreational fishing on the Souhegan River. The protected flows for fish habitat resources are discussed in Part 1, Section VII of this report.

III.) Pubic Water Supply

Public water supplies located along the Souhegan River are dependent upon surface water or groundwater sources, with the later being the principal supply source. The only active public surface water supply source identified along the Souhegan River was the Town of Greenville's Water Works. The town of Greenville's water supply is the Tobey Reservoir, which is located in Temple, NH just off of Route 45 (Figure 5). The Tobey Reservoir is a constructed impoundment on the divide of Temple Brook to the north and an unnamed tributary to the Souhegan River to the south. Temple Brook flows into Blood Brook in Wilton, which discharges into the Souhegan River near the Town of Wilton's Water Supply wells. The unnamed tributary flows to the south and discharges into the Souhegan River approximately 1.3 miles downstream of Greenville.

Table 3. New Hampshire Fish and Game Department Stocking Records for the Souhegan River during 2004.

Total Fish Stocked in the Souhegan River - 2004				
Town	**Species**	**Age of fish**	**lbs of fish**	**lbs of fish**
AMHERST	BT	1+YR	700	350
AMHERST	EBT	1+YR	650	305
AMHERST	RT	1+YR	780	780
GREENVILLE	EBT	1+YR	600	313
GREENVILLE	RT	1+YR	450	450
MERRIMACK	BT	1+YR	800	400
MERRIMACK	RT	1+YR	200	200
MILFORD	BT	1+YR	1,350	585
MILFORD	EBT	1+YR	820	425
MILFORD	RT	1+YR	1,125	1125
NEW IPSWICH	EBT	1+YR	600	300
NEW IPSWICH	RT	1+YR	750	750
WILTON	BT	1+YR	1,350	585
WILTON	EBT	1+YR	1,030	508
WILTON	RT	1+YR	975	975

BT – Brown Trout, EBT – Eastern Brook Trout, RT – Rainbow Trout

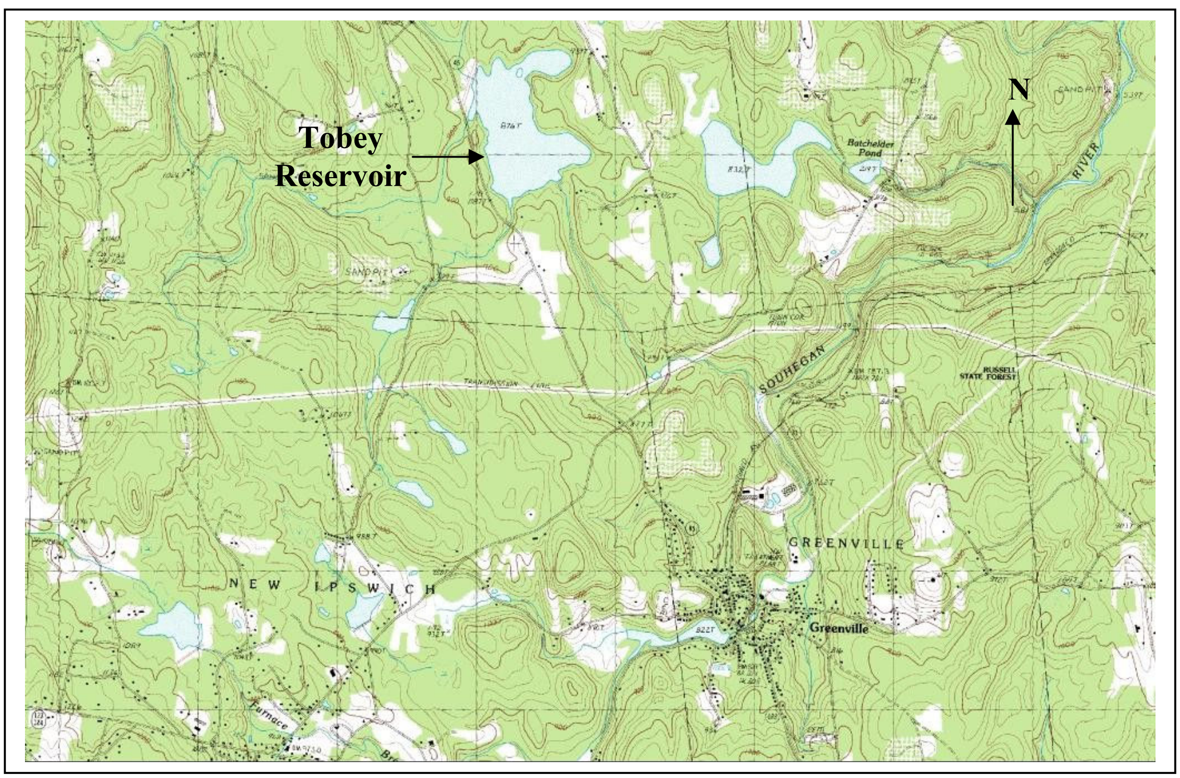


Figure 5. Location of the Greenville Water Supply, the Tobey Reservoir. USGS Greenville Topographic Quadrangle 1988.

No direct diversion of water from the main stem of the Souhegan River is used by the Town of Greenville Water Works for the Tobey reservoir. The reservoir captures flow from two small drainages (Gambol Brook and an unnamed stream) located west of Route 45. Water is then withdrawn from the reservoir and treated before its distribution. The water treatment facility is run by a private contractor (Woodard & Curran) and it is capable of treating 0.25 million gallons of drinking water per day.

Water use data for the Town of Greenville Water Works for the period of 1999 through 2004 were obtained from the State of New Hampshire and is summarized in Table 4. Water use varies from year to year and by month to month. The minimum monthly water use in Greenville during this period was 1,922.7 thousand gallons (June, 2004) and a maximum of 7,322.8 thousand gallons (May, 2001) with an average of 4,515.8 thousand gallons. The daily water use, when converted to cubic feet per second, ranges from a minimum of 0.20 cfs to a maximum of 0.25 cfs with an average of 0.23 cfs.

The Greenville Water Works does not directly withdraw water from the Souhegan River, but does impound tributary flow, which is then used as a Public Water Supply. Since this system is not directly dependent upon the flow in the Souhegan, the flow protection goal for this IPUOCR is zero.

The remaining Public Water Supply systems along the Souhegan River utilize groundwater as their supply source. These include:

- Wilton Water Works
- Milford Water Works
- Pennichuck Water Works, including:

  Badger Hill – Milford
  Souhegan Woods – Amherst
  Amherst Village District – Amherst

Since each of these systems is dependent upon groundwater they are not considered as being dependent upon flow within the Souhegan River. As a result, no specific PISF is proposed for these groundwater Public Water Supplies.

Table 4. Summary of Town of Greenville Water Works Water Use (Thousands of gallons per month) for 1999 through 2004.

YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max.	Min.	Mean
1999			5621.4	5762.5	5942.6	5938.2	4989.9	4109.1	5167.4	5418.7	4461.6	4534.3	5942.6	4109.1	5194.6
2000	4912.3	4830.5	5627	5660.3	5685.3	6150.6	5762.5	5854.889	5621.79	5154.178	5030.5	5440.9	6150.6	4830.5	5477.6
2001	5692.1	6136.2	6374.7	5939.2	7322.8	7052.1	5616	4956.1	4690.3	4878	4581.2	4144	7322.8	4144.0	5615.2
2002	3509.1	3373.5	3352.4	3576.1	3913.4	4273.8	4986.5	4762.7	3939.3	3908	3509.9	3254.3	4986.5	3254.3	3863.3
2003	3309.9	3116.2	3517.2	3423.1	3679.8	4083	4253.9	3977.9	3718.7	4408.6	3307.5	3194	4408.6	3116.2	3665.8
2004	3646.1	3219	3696.8	3368.1	1923.3	1922.7	4367.7	4605.1	3802.4	3821.2	3380.4	3633.1	4605.1	1922.7	3448.8
Years	5	5	6	6	6	6	6	6	6	6	6	6			
Average (gallons/ month)	4,213,900	4,135,080	4,698,250	4,621,550	4,744,533	4,903,400	4,996,083	4,710,965	4,489,982	4,598,113	4,045,183	4,033,433	4,996,083.3	4,033,433	4,515,873
Daily (gpd)	135,932	147,681	151,557	154,052	153,049	163,447	161,164	151,967	149,666	148,326	134,839	130,111	163,447	130,111	148,483
Daily (cfs)	0.21	0.23	0.23	0.24	0.24	0.25	0.25	0.23	0.23	0.23	0.21	0.20	0.25	0.20	0.23
Daily (cfsm)															

Notes:

Source of Town of Greenville water supply is the Tobey Reservoir, not the main stem of the Souhegan River.
Source of water use information - NHDES

IV.) Pollution Abatement

There are currently three permitted wastewater discharges to the Souhegan River or an immediately adjacent tributary to the river. Two of these are municipal wastewater treatment plant (WWTP) discharges (towns of Greenville and Milford), while the third is from a State of New Hampshire fish hatchery which discharges directly into Purgatory Brook, approximately one half mile upstream of its confluence with the Souhegan River. The town of Wilton also has a WWTP, but its treated wastewater is pumped to Milford's collection system and discharged by Milford through their permitted outfall. Table 5 delineates some of the effluent limitations for these wastewater discharges.

Table 5. Details of permitted wastewater discharges in the Souhegan River designated reach.

Facility	Effluent Limitations				
	Design Flow (MGD/cfs)	Maximum Daily BOD (lbs/day	Maximum Daily TSS (lbs/day)	Whole Effluent Toxicity	
				LC50, % effluent	C-NOEC, % effluent
Greenville WWTP	0.233/0.36	287	538	100	28
Milford Fish Hatchery	2.74/4.24 maximum reported	none	324	none	None
Milford WWTP					
Summer	2.15/3.33	287	538	100	14.5
Winter	2.15/3.33	448	628	100	14.5

Source: Individual National Pollution Discharge Elimination System Permits

In addition, there is a suite of other parameters that each permittee must monitor, most of which are for monitoring purposes only and have no specified effluent limitations. Effluent limitations are generally only attached to NPDES permits for those parameters that either reflect required treatment plant operational efficiencies (e.g. pollutant removal efficiencies equivalent to secondary treatment) or which have the potential to cause a violation of water quality standards in the receiving water.

According to Env-Ws 1705.02 of the State's surface water quality regulations (NHDES, 1999), the river flow used to calculate permit limits for aquatic life criteria and human health criteria for non-carcinogens for NPDES permits is "7Q10". The 7Q10 is the average seven day low flow that occurs, on average, once every ten years. Use of 7Q10 for establishing waste discharge permit limits means that when river flow is at or above 7Q10, the permitted discharges would not, by themselves, cause water quality in the river to be less than applicable water quality criteria. Consequently, the protected instream flow (PISF) necessary for pollution abatement in the Souhegan is 7Q10 at the points of discharge. These pollution abatement PISFs are provided in table 6.

Table 6. Protected Instream Flow (PSIF) for Pollution Abatement in the Souhegan River.

River section	PSIF (7Q10)[1]
MA border to Greenville WWTP	No pollution abatement PISF required
Greenville WWTP to Milford WWTP	2.1 cfs (0.068 cfsm) (estimated 7Q10 at Greenville WWTP
Milford WWTP to the Merrimack River	9.4 cfs (0.067 cfsm) (estimated 7Q10 at Milford WWTP

[1]Estmated from hydrologic evaluation presented in Appendix 3

V.) Hydroelectric Energy Production

Information on hydropower operations in the Souhegan River watershed was obtained through interviews with affected dam owners (ADOs) and examination of records maintained by the NHDES Dam Bureau. Detailed profiles of the hydroelectric facilities and information on the dam specifications can be found in Appendix 1. This information was essential to fully understand the relationship between flow and energy production at each of these facilities. The impoundments behind each of the dams are small and riverine and consequently have minimal storage capacity. Each of the four active generating facilities on the Souhegan River is operated as "run-of-river", which means that inflow should equal outflow at all times. The use of temporary flashboards, or pulsing the flow by turning on and off the generators, would result in an imbalance between reservoir inflow and outflow.

The river corridor currently contains seven hydroelectric facilities, four of which are actively generating electricity (Table 7).

Table 7. Hydroelectric facilities on the Souhegan River designated reach.

Facility	State Reference Number	Location	Status	Flow Generation Capacity	
				Minimum (cfs/cfsm)	Maximum (cfs/cfsm)
Waterloom[1]	NH00355	New Ipswich	Active	15-17/0.66-0.75	?
Otis[1]	NH00041	Greenville	Active	20/0.67	?
Chamberlain/Souhegan III[1]	NH02007	Greenville	Active	20/0.68	?
Souhegan (Elderly Housing)	NH02006	Greenville	Inactive	Not applicable	Not applicable
Label Arts/Souhegan III	NH00906	Wilton	Inactive	Not applicable	Not applicable
Wilton Hydro Dam	NH00905	Wilton	Inactive	Not applicable	Not applicable
Pine Valley Mill[2]	NH00258	Wilton	Active	42.2/0.44	?

[1]Personal Communication, Alden Greenwood, 2006
[2]Personal Communication, Heidi Heller-Blackmer, 2006

As can be seen from the Table 6, hydroelectric energy production is dependent on river flow. Most power is generated at mid-flow ranges since it is seldom economical to install equipment necessary to generate power at very low or very high flows. For the Souhegan hydroelectric facilities, minimum flow requirements range from about 15-42 cfs (0.44-0.75 cfsm), depending on the facility, while maximum flow capacity is limited to flows below _____cfs (______cfsm). Consequently, the hydropower PISFs for Souhegan hydroelectric power production likewise range from lows of 0.44 – 0.75 cfsm to highs of ______cfsm, depending on the particular facility.

Examination of the 2000-2004 streamflow record for the Souhegan indicates that streamflow is generally insufficient to generate power during the summer and early fall and periodically throughout most of the rest of the year. Only during the spring and early summer is streamflow dependably high enough to generate power, and even then it is occasionally too high for optimal production. Since the hydrologic analysis presented in Section III (Water Supply) indicates that AWUs have no ability to reduce flows to the Greenville hydroelectric facilities, and by at most 1 cfs (at most 2% of generation capacity and typically much less) for the Pine Valley Mill facility, it is concluded that the existing system meets the hydroelectric PISF for the Souhegan River to the extent naturally possible.

Nevertheless, it is conceivable that some management alternatives to maintain other PISFs could change the frequency of occurrence of certain higher flows events and could therefore affect hydroelectric energy production. An example of a management strategy that could influence hydroelectric production is utilization of selected flood control impoundments for more or less permanent storage of water to be used for flow augmentation during low flow conditions. While it is likely that water so stored would be obtained by “flood skimming”, when river flows are in excess of hydro PISFs, there still could be some impacts under lower flow conditions. Furthermore, release of these stored waters would be unlikely to be of use for hydroelectric production since flow augmentation needs would likely be at times when river flow is well below the hydroelectric facility PISFs. If such management strategies become part of the Souhegan Water Management Plan, potential impacts to hydroelectric operations will be addressed at that time.

VI.) Fish and Wildlife Habitat

Study Area

Based on the reconnaissance survey of aquatic habitat the Souhegan River was divided into eight reaches with multiple sections within each reach. Representative sections were then selected as sites for the habitat surveys (Figure 6)

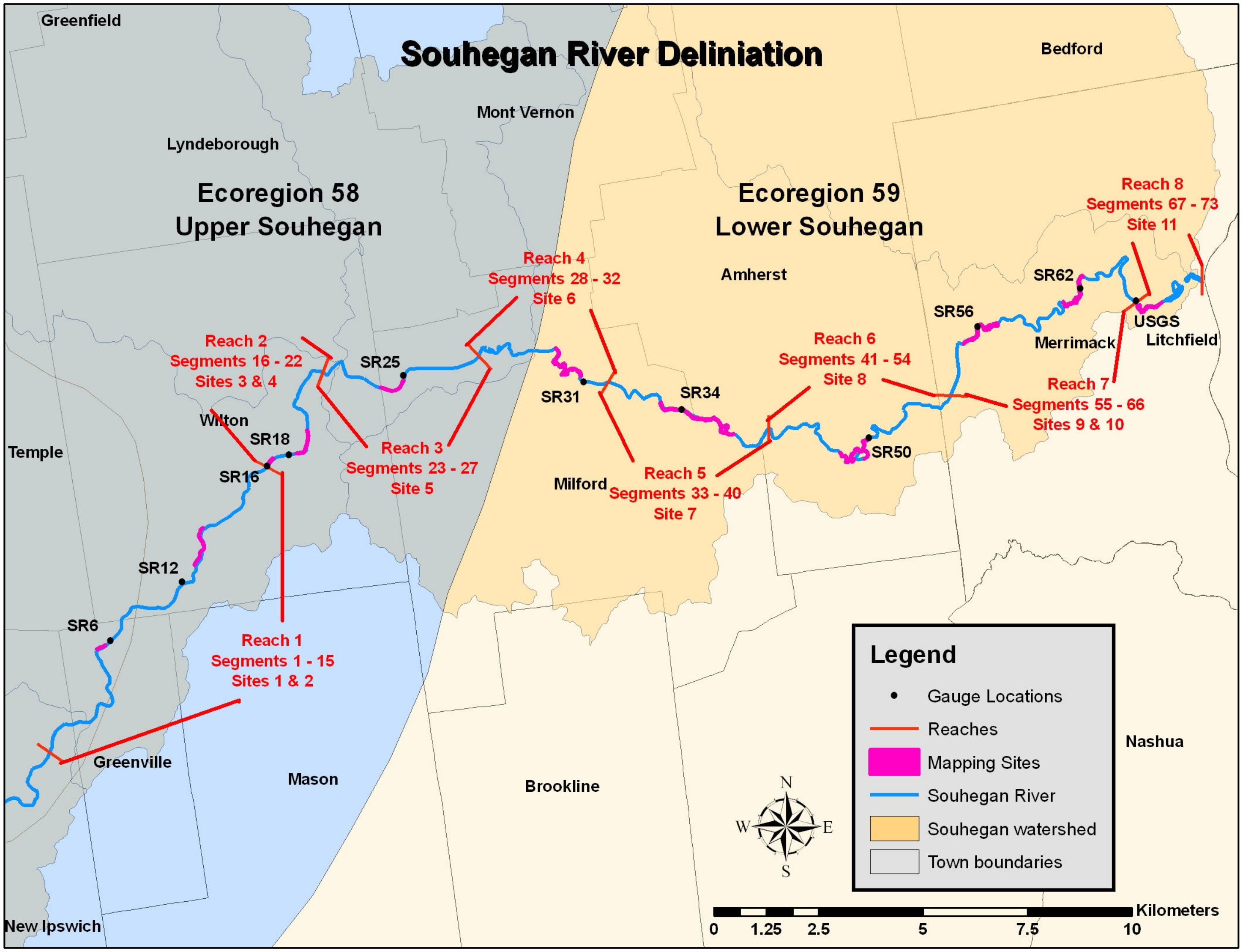


Figure 6. Map defining terminology of study regions. Study area of the Souhegan River shown in blue. Upper and Lower Souhegan zones are defined by Ecoregion. The eight reaches are labeled in red and include their defining segments. Representative mapping sites are shown in pink and labeled sequentially downstream.

Reach 1: (Sections 1 – 15; 11.19 km)
For approximately 11.2 km at the uppermost length of the designated reach, the Souhegan River flows through forested areas and is therefore heavily shaded with large amounts of overhanging vegetation and noticeable woody debris. The substrate consisted primarily of large cobble and bedrock, with small amounts of sand. Geomorphically, the river is dominated by step-pool sequences. Where the Souhegan River runs parallel to Route 31 for 5 km, the banks were sometimes stabilized by riprap and the morphology of short stretches had been altered. Within the river channel, there were discarded pieces of riprap, which alter the substrate and aquatic habitats. Eight percent of the length is impounded by a dam in Greenville. Section numbers 6 (Site 1) and 12 (Site 2) were selected as representative sites of this reach.

Reach 2: (Sections 16 – 22; 3.51 km)
Below the bridge next to the Monadnock Springs bottled water company (sections 17-22), the river flows into an open space, although the banks remain mostly forested. In the vicinity of section 21 and 22, the river flows through the Horseshoe Gorge. In this reach, the habitat types changed including more runs and glides than found upstream. Sections 16 (Site 3) and 18 (Site 4) were selected as representative sites of this reach.

Reach 3: (Sections 23 – 27; 4.63 km)
Beginning with section 23, which is impounded, the Souhegan River provides a dramatic contrast to upstream sections in terms of human induced alteration. Directly above the confluence with Stony Brook the Souhegan River enters urbanized areas with heavily stabilized banks. The confluence itself was created and enforced by old mill buildings and bridge crossings. Almost immediately after the confluence, two dams impound the river. Below the dams, the Souhegan River has been realigned as a part of highway construction all the way down to section 27. Twenty-five percent of the 4.6 km length of Reach 3 is impounded.

In this reach the river still had a moderately high gradient yet substrate size reduces to cobble, pebble, and gravel. The habitat type was dominated by glides and riffles. Consequently the boulder and woody debris cover was strongly reduced and banks are stabilized by riprap. Shallow margins (abundant upstream of this reach) were absent. Nevertheless, there was some overhanging vegetation and canopy cover shading. Section 25 (Site 5) was selected as the representative site of this reach.

Reach 4: (Sections 28 – 32; 4.18 km)
The river changes to a low gradient, wide, (20 m) meandering channel. This low gradient continues down to our section 32 and is accompanied by fields covered with remnants of oxbows and former side arms. This approximately 4.18 km long reach has no dams. A number of tributaries join the river in this area.

The substrate changed very dramatically to a high abundance of sand and fines. The riverbanks became steep but covered with overhanging canopy that provides shade and a source of woody debris. The habitat types consisted of runs, pools, glides and riffles. The presence of mussels and dragonflies were first observed in this section. Section 30 (Site 6) was selected as the representative site of this reach.

Reach 5: (Sections 33 – 40; 5.27 km)
Section 33 crosses the town of Milford where the river is impounded by two dams over the length of approximately 1.5 km. This 1.5-km stretch comprises 28% of the total length of this reach. Downstream of the dams (section 34 and 35), the river continues to flow through residential areas and is high gradient. It cuts through bedrock ledge, which is also expected under the impoundments. The river banks in this area have an abundance of riprap as well as overhanging vegetation that does not provide much shading, but indicates the age of the construction. Some woody debris was observed. Downstream of the impoundment the habitat consisted of rapids, riffles, and runs with coarse but mixed substrate embedded in sand. Sections 34 through 37 (Site 7) were selected as the representative sites of this reach.

Reach 6: (Sections 41 – 54; 7.08 km)
Nearly 5 km of this reach is accompanied by a golf course that reduces canopy shading and woody debris. Meandering banks were active and if a forest were present the trees along these eroded banks may find their way into the river channel, increasing woody debris and substantially changing river morphology. In the areas of bridges was observed heavy bank stabilization with riprap. The substrate was dominated by sand with the presence of submerged underwater vegetation. Hydraulic habitats consisted of runs, pools, and glides accompanied by some low gradient riffles.

Beginning with section 48 the Souhegan River meanders through more forested and residential areas where the abundance of woody debris and canopy shading increases. Also observed were increases in shallow margins and the appearance of a few backwaters. Submerged underwater vegetation was less abundant. The banks were still high and eroded. The hydraulic habitat consisted of runs, pools, and glides accompanied by low gradient riffles associated with woody debris. Sections 47 through 50 (Site 8) were selected as the representative sites of this reach.

Reach 7: (Sections 55 – 66; 9.36 km)
The river turns into a mosaic of long, low gradient stretches interrupted by ledges and large rapids. The river meandered less than it did upstream and the oxbows were less abundant indicating steeper topography of the surrounding landscape. The riverbanks continued to be high and steep, and were covered with mature vegetation. The 9.3 km long reach had no impoundments but riverbanks were associated with residential use.

The dominating substrate continued to be sand with the exception of bedrock in rapids. The river becomes over 30 m wide such that canopy shading does not reach across its width. The hydraulic habitat was dominated by runs, riffles, pools, and glides accompanied by cascades and backwaters. Sections 56, 57 (Site 9) and 61, 62 (Site 10) were selected as representative.

Reach 8: (Sections 67-73; 2.16 km)
Downstream of Wildcat Falls the river flows though the residential and urbanized town of Merrimack. The amount of cascades and ledges significantly increased (there were three

cascades in this reach). Therefore the river had more moderate to high gradient character and did not meander. Of the approximately 2.1 km length of this section, an inactive dam impounds 16% of the length. These impoundments created substantial wetlands.

The hydraulic habitat consisted of runs, riffles, and cascades with an abundance of boulders. Woody debris and shallow margins were present. At the bridge and residential areas the banks were stabilized with riprap. Substrate was a mixture of bedrock, cobble, gravel, sand and fines. Sections 67 through 71 (Site 11) were selected as the representative sites of this reach.

Segments of the Souhegan River

Based on the physical characteristics of the river observed during the initial survey and described herein, distinct geomorphologic differences between the upper (Reaches 1-3) and lower (Reaches 4-8) Souhegan River were apparent. Below, the valley began to widen and the gradient of the river became less steep. There was also a noticeable change in the dominant substrate type in the river below this point, from large cobble and boulders with bedrock outcrops, to a dominant substrate type of sand and fine gravel. These sudden changes coincide with the approximate location of the Milford-Souhegan glacial-drift aquifer, an area of unconsolidated glacial-drift deposits consisting primarily of stratified sand and gravel overlain by more recent alluvium (Harte, 1992).

The area of the river where these changes occur also coincides with a zoogeographic Ecoregion boundary (Omernik, 1987). The upper portions of the Souhegan River are within Ecoregion 58, the Northeastern Highlands, and the lower portions of the river extend into Ecoregion 59, the Northeastern Coastal Zone.

The combined effects of changes in gradient, stream order, and surficial geology caused a dramatic change in the dominant substrate type and created a difference in the available habitat types between the upper and lower portions of the river. This led to the believe that there would be differences in the composition of the instream faunal communities between the upper and lower portions of the river.

To account for these expected differences in the fauna, the river was divided into two primary segments: Upper Souhegan River (Reaches 1-3), representing a 3rd order, high gradient stream, and Lower Souhegan River (Reaches 4-8), representing a 4th order, low gradient river. The status of the instream faunal assemblages of these two river segments was investigated, analyzed, and evaluated separately.

Temperature Data

Ten Hobo® temperature probes (Onset computer corporation, Bourne, MA) were installed throughout a 52 km study area starting from the New Ipswich, NH impoundment and ending at the Merrimack River confluence. Temperatures were recorded in the Souhegan River between June 26, 2004 and September 13, 2005. This was a period of 437 days including portions of two summer seasons. Several temperature probes were lost during the ice breakup and floods during the spring of 2005 and could not be replaced until flows subsided enough to enter the river in late June. This loss limited the number of overlapping days from the two seasons studied. Between 200 and 435 days of temperature data were recovered from each site, which accounts for over 80,000 individual temperature measurements. The location of the temperature probes and points of interest can be seen in Figure 7.

Information regarding the impoundments indicated in Figure 7 may be found in Table 8. The description column attempts to qualify the observed relative size of impoundment. The column named "Reference" gives distance up/downstream from nearest temperature probe and the column named "Distance" gives the downstream distance from the New Ipswich impoundment starting location.

Table 8. Impoundments and points of interest along the Souhegan River. Each location includes a brief description of the impoundments relative size or other descriptive information. The reference column refers to the features distance (in meters) up or down-stream from the nearest temperature probe location. The column "distance" is the location of the feature (in meters) downstream from the starting location at the New Ipswich impoundment.

Location	Description	Reference	Distance (m)
Impoundment 1	Large, start of Designated River	New Ipswich impoundment	0
Impoundment 2	very small	963 m downstream Impound1	963
Impoundment 3	Large	9943 m upstream Probe 2	3788
Monadnock Wells	Bottling Plant	76 m upstream Probe 2	13481
Impoundment 4	Very Small	31 m upstream Probe 3	17198
Impoundment 5	Large	137 m upstream Probe 4	18798
Impoundment 6	Large	2142 m upstream Probe 5	28371
Waste Water	Treatment Plant	15 m upstream Probe 5	30645
Impoundment 7	med/large	576 m upstream Probe 10	51521

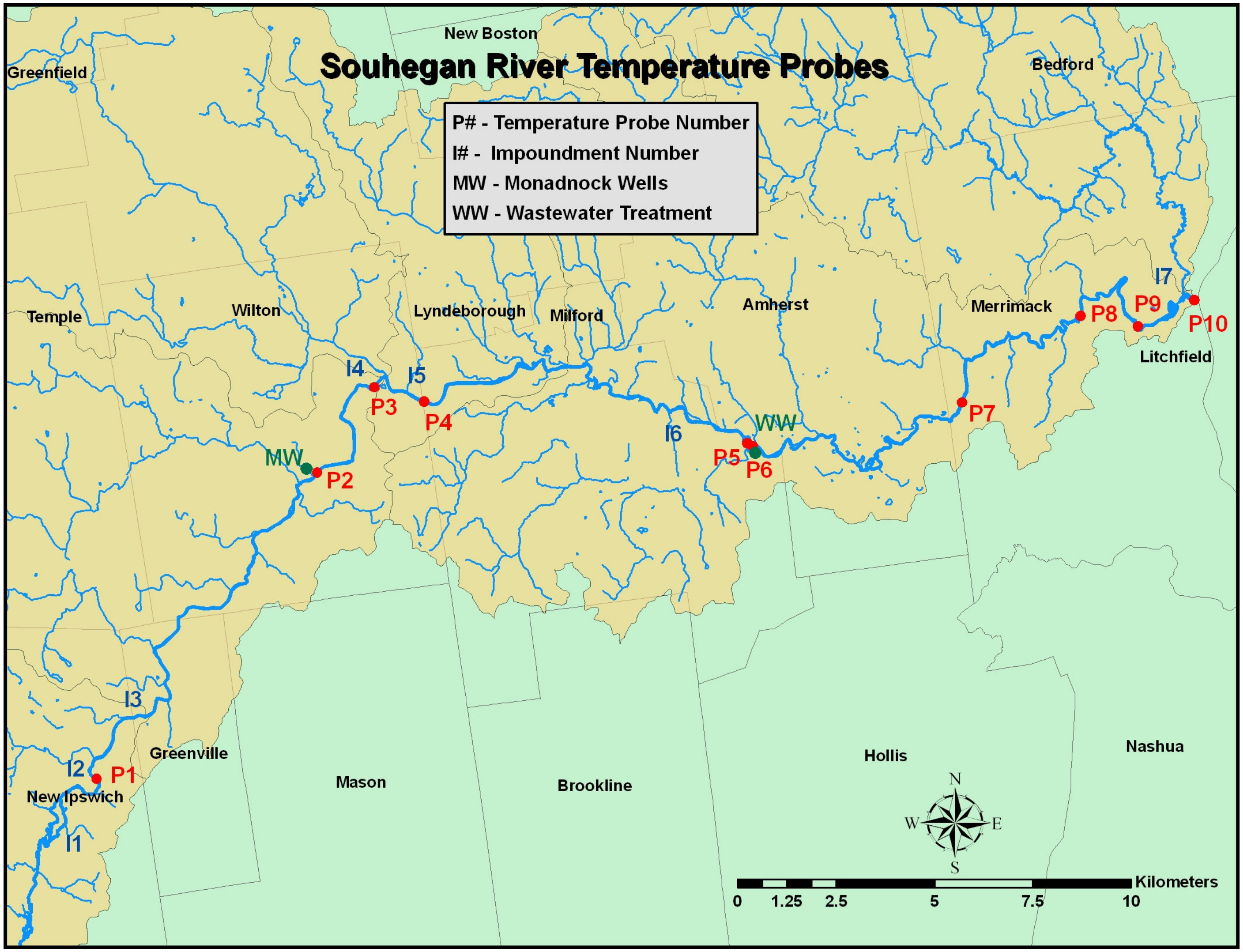


Figure 7. Map showing the location of temperature probes (Red), impoundments (Blue I-numbers), and other points of interest (Green) on the Souhegan River.

2004 Temperature Results

The most rigorous comparison of the temperature data collected, because of the loss of several over-wintering probes, was to compare only the overlapping days from the two seasons for all temperature probes. This restriction therefore limited the comparison to a 64-day period from July 2nd to September 3rd for both the 2004 and 2005 seasons (Table 9).

Table 9. River Water Temperature Data for the 2004 Field Season. The column "Distance (m)" provides the distance in meters between a probe and the closest upstream probe. The column "Distance from Impoundment (m)" provides the probe's downstream distance in meters from the New Ipswich, NH impoundment. The columns "Min Temp" and "Max Temp" were created by filtering the maximum or minimum hourly temperature registered during the period of investigation (recorded in degrees Celsius). The column "Avg. Temp" was created by averaging the daily average temperature data for the period of record and is reported in degrees Celsius.

Temperature Probe	Distance (m)	Distance from Impoundment (m)	Min Temp. (°C)	Max Temp. (°C)	Avg. Temp. (°C)
1	0	1110.6	**18.7**	**24.8**	**21.4**
2	12446.7	13557.3	**14.1**	**26.0**	**19.6**
3	3671.8	17229.2	**14.9**	**27.5**	**20.5**
4	1705.8	18935.0	**17.1**	**27.9**	**20.7**
5	11578.0	30513.0	**12.9**	**28.7**	**21.1**
6	147.5	30660.5	**17.1**	**27.9**	**21.0**
7	9641.3	40301.8	**17.5**	**28.3**	**21.0**
8	6210.7	46512.5	**17.9**	**28.3**	**20.9**
9	3618.1	50130.6	**17.9**	**29.5**	**21.5**
10	1966.1	52096.7	**18.3**	**33.2**	**21.7**

2005 Temperature Results

Data for the period of comparison were compiled in Table 10 and follow the same column format as Table 9. Probe 6 became buried under sediment in the middle of July and after that date it recorded a modified temperature that most likely included insulation and a strong groundwater component from the adjacent steep bank. It was therefore removed from the longitudinal profile graph for the 2005 season.

Figure 8 is a longitudinal temperature profile for the period between July 2, 2004 and September 3, 2004.

Table 10. River Water Temperature Data for the 2005 Field Season.

Temperature Probe	Distance (m)	Distance from Impoundment (m)	Min Temp. (°C)	Max Temp. (°C)	Avg. Temp. (°C)
1	1110.6	1110.6	**19.1**	**26.8**	**23.2**
2	12446.7	13557.3	**14.4**	**27.5**	**20.9**
3	3671.8	17229.2	**16.0**	**28.7**	**21.4**
4	1705.8	18935.0	**15.9**	**28.3**	**21.9**
5	11578.0	30513.0	**16.4**	**28.7**	**22.5**
6	147.5	30660.5			
7	9641.3	40301.8	**16.8**	**25.6**	**21.7**
8	6210.7	46512.5	**16.7**	**27.1**	**22.3**
9	3618.1	50130.6	**16.7**	**26.3**	**22.5**
10	1966.1	52096.7	**12.9**	**29.1**	**22.7**

In 2004, average river water temperatures during this study period tended to cool downstream, after leaving the New Ipswich impoundment, for approximately 14 km until the area between the Monadnock bottling plant (intersection of Route 31 and 101) and the small impoundment located near Island Street (Wilton). Downstream of Wilton, temperatures remained fairly constant or rose slightly until the area between probes 8 and 9. Downstream of Turkey Hill Road (Merrimack) temperatures began to increase more noticeably at the probes located in Wildcat Falls and at the Merrimack River confluence.

Average temperatures during the 2005 study period also tended to cool, after leaving the New Ipswich impoundment, downstream for approximately 14 km until the area between the Monadnock bottling plant (intersection of Route 31 and 101) and the small impoundment located near Island Street (Wilton). Downstream of Wilton temperatures rose slightly until probe 5 or 6 at the Milford wastewater treatment plant. Arrowed lines (Figure 9), indicating likely temperature trends, were added to the graph between probes 5 and 7 because of the loss of temperature probe 6. Average temperatures decreased slightly during the study period between probes 5 and 7 before increasing gradually to the Merrimack River confluence (Figure 9).

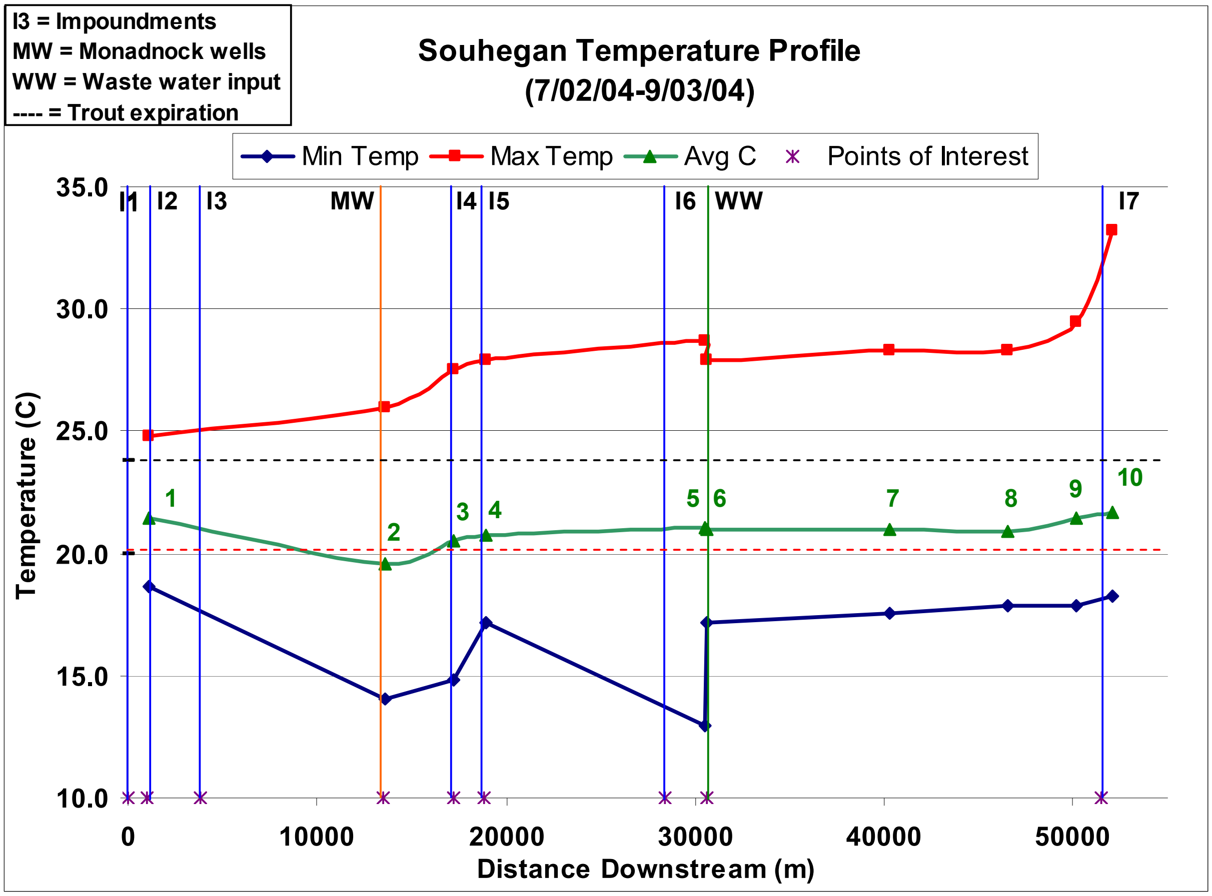


Figure 8. Souhegan River longitudinal temperature profile for the period of days common to the 2005 temperature data. Temperature probe locations (shown as square, triangle, and diamond symbols in Figure 10) are plotted by their downstream positions in relation to the New Ipswich, NH impoundment and are labeled with green numbers. Maximum temperatures are shown in red, minimum in blue and period averages in green. Horizontal lines refer to points of interest along the study length of the river (see Table 8). A red dashed line at 20 ºC represents the upper optimal temperature range for Eastern brook trout (EBT). The black dashed line at 23.8 ºC represents the maximum tolerable temperature for EBT where fast moving/turbulent water and high oxygen levels exists.

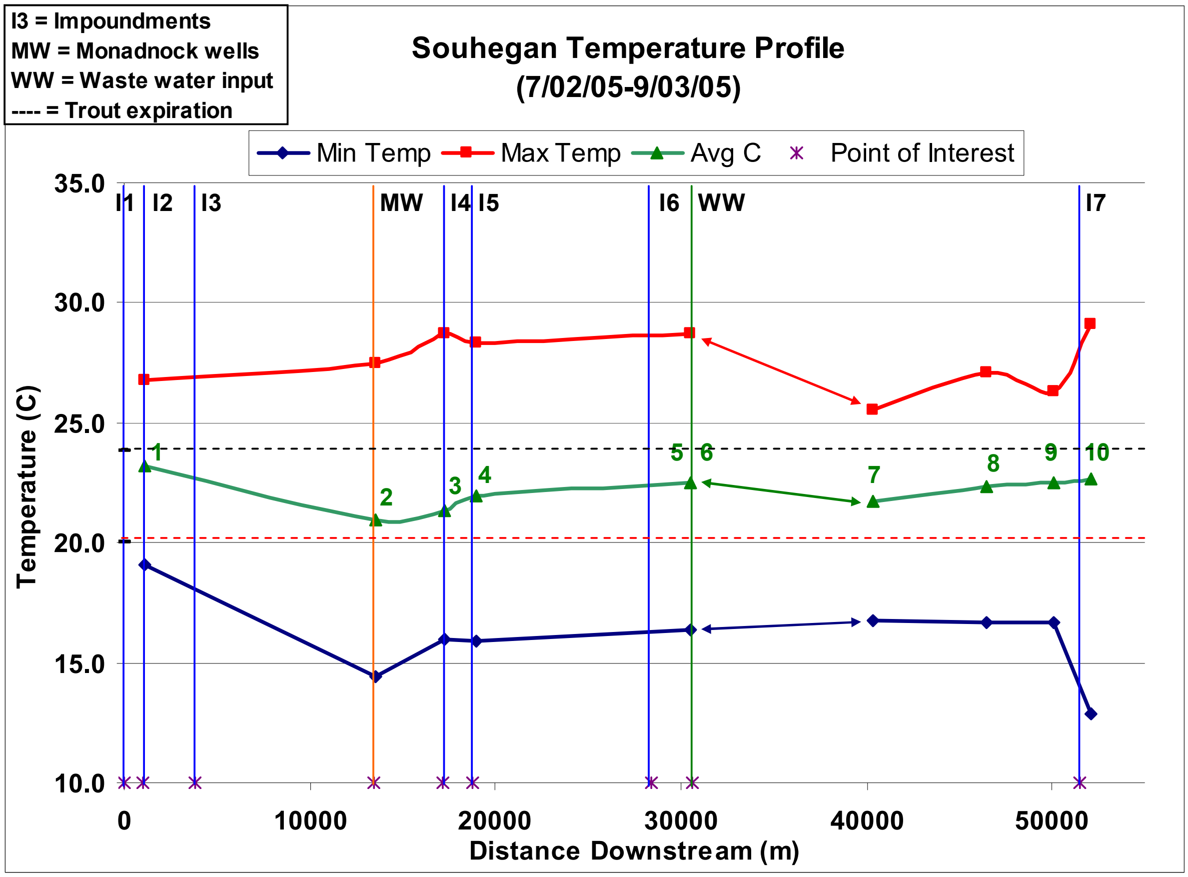


Figure 9. Souhegan River longitudinal profile for the period of days common to the 2004 temperature data. Extreme minimum (blue) and maximum (red) temperatures are plotted for the period of record. Horizontal green line shows average temperature at each probe location plotted by distance from the New Ipswich impoundment. Vertical lines refer to points of interest along the river; impoundments are shown in blue, the Monadnock bottling plant in orange, and the Milford wastewater treatment plant in green.

There are numerous flood protection reservoirs located in the headwaters of the Souhegan River watershed. Observation of elevated water temperatures in the Upper Souhegan lead to the suspicion that these shallow impoundments may be a strong contributor to high temperatures through their absorption of solar radiation. Therefore, on a hot day of August 8, 2005 an investigation of water temperatures within impoundments and their outflows at multiple locations was conducted. Temperatures were measured using a non-contact thermometer at the waters surface both upstream and downstream of each impoundment. Water temperatures of impoundment outflows ranged between 21.1°C below the New Wilton Reservoir and 32.7°C at the northern outflow of Senator Toby Reservoir (Site 12 B) in Temple, New Hampshire. Temperature measurements and site locations are given in Table 11.

Table 11. Locations and water temperature measurements of impoundments within the Upper Souhegan River watershed.

Date	Time	Water body name/Dam Site	Pond Temp. (°C)	Outflow Temp. (°C)
8/8/2005	10:00	New Wilton Reservoir	28.6	21.1
8/8/2005	10:30	Unknown	21.4	22.5
8/8/2005	11:00	Site 15 Dam (Batchelder Pond)	26.6	23.3
8/8/2005	11:30	Site 12A North	26.6	28.3
8/8/2005	11:45	Site 12 A South	32.7	32.7
8/8/2005	13:30	Water Loom Pond	29.7	26.6
8/8/2005	14:30	Site 19 Dam	27.2	29.4

Temperature Discussion

Average temperatures in the two summer seasons studied follow remarkably similar trends for the 64-day period. The only two exceptions were the slight dip in average temperatures at Probe 7 located near Seaverns Bridge in Merrimack and the increase in the 2005 average temperatures by 2 degrees Celsius at each probe.

Temperatures in the upper watershed are dramatically influenced by several impoundments on the tributaries. During summer, even the lowest Souhegan River water temperatures are high in regional comparison. It takes at least 14 km for the river waters to cool and mix with groundwater. Average temperatures begin to increase near the Monadnock Springs bottling plant and below each of the two downstream impoundments before leveling off and remaining constant or slightly rising over the next 30 km of river. The water temperature of the Merrimack River may influence the probe located at the Souhegan/Merrimack River confluence during certain flows.

Daily average temperatures remained above the maximum optimal temperature range for brook trout in both periods of record (with the exception of Probe 2 in the 2004 season). Daily average temperatures approached the maximum survival temperature for brook trout in fast-flowing, oxygenated waters during the two periods of study. Maximum daily temperatures during both periods of study far exceeded the water temperature requirements for brook trout. These temperature thresholds could also apply to other cold water based fish species like slimy sculpin, Atlantic salmon, longnose sucker and transitional species like longnose and blacknose dace.

Bio-Periods

The flow regime, and the flow requirements of fauna within a stream vary through the course of a calendar year. When attempting to prescribe flows in a regulated river, it is necessary to take into consideration these flow and habitat fluctuations. To achieve this, the calendar year was partitioned into seasons, or biological periods (bio-periods) when migratory species and specific life stages of resident fauna are particularly dependent upon appropriate flows. These bio- periods reflect the special or critical times that the availability of habitat required by a particular fauna or life stage may be dependent upon flow conditions.

The timing and duration of these bio-periods was determined using a literature-based analysis of the life histories and biological needs of the resident target species identified in the Target Fish Community section (TFC) (section IX of this report), and the fluvial dependent, diadromous pulse species that have the potential to occur within the Souhegan River. The timing of these seasonal bio-periods was then compared to the flow conditions of the Souhegan River using a hydrograph of mean daily flow records reported for the U.S. Geological Survey's Souhegan River gauge at Merrimack, New Hampshire (based on 71 years of record) (Figure 10).

Spring/fall spawning and low flow summer survival/rearing and growth conditions were considered the primary biological periods of importance based on professional experience in fish ecology and instream flow studies. Over-winter survival and salmonid egg development and the spring flood/storage periods, were evaluated solely by the simulated hydrograph since data for the targeted fauna were extremely sparse for these two periods.

The spawning periods of the top five target resident species in the TFC were selected and the two selected extirpated anadromous species (Atlantic salmon and American shad) from literature sources (Armstrong et al. 2003; Hartel et al., 2002; Ross and Reed, 1978; Scarola, 1987; Smith, 1985; Stier and Crance, 1985; Whitworth, 1996).

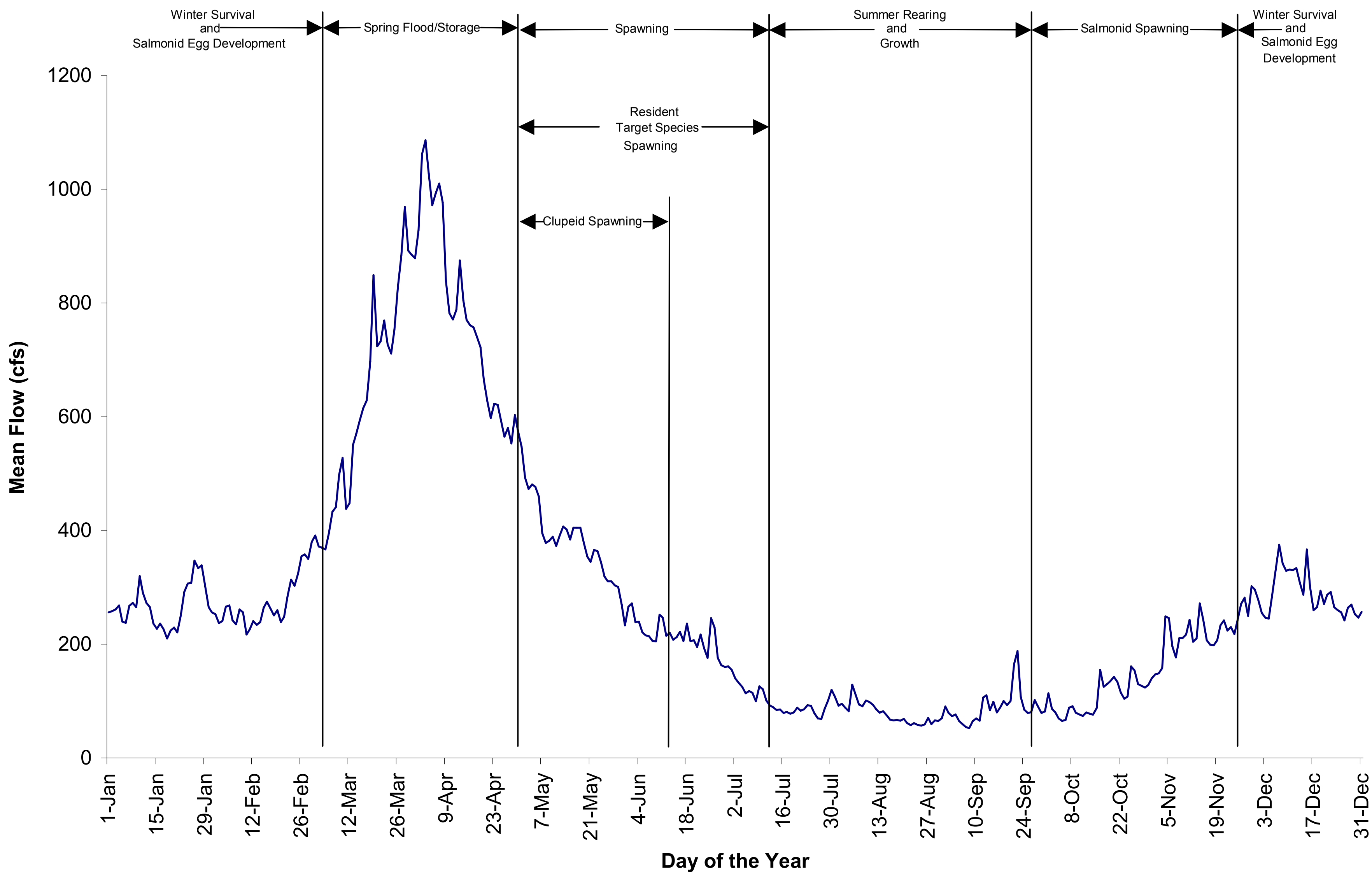


Figure 10. Selected bio-periods for the Souhegan River displayed over the Souhegan River daily mean hydrograph based on 71 years of record.

Wetland/Riparian Wildlife Habitat

Many species of wildlife were observed to use the deep and shallow oxbow marshes, backwaters, floodplains, and riparian edges along the Souhegan River. Table 12 lists the species observed during the field reconnaissance and transect surveys. Although the list is not a complete list of species potentially using the river, it includes some of the more common species and those easily detectable by song or track. Wildlife species that have an aquatic life phase for which water levels are critical, such as frog eggs and larvae, and those that forage principally on flow-dependent prey during a critical life phase (brood rearing, migration) such as swallows, kingfishers and bats, are more flow dependent than mobile terrestrial species that forage opportunistically in the wetlands (e.g. deer, chipmunks). Flows that deviate substantially from the natural flow paradigm during the growing season (April through October) are likely to have the most significant effects on flow-dependent wildlife, as the adaptive behaviors and food chains may be upset. For example, higher flows in early summer may destroy waterfowl nests, while lower flood levels in spring may fail to fill oxbow marshes where amphibians breed. Water temperature changes that alter the timing of macroinvertebrate life cycles (for example, emergence of insects important to breeding or migrating songbirds) could also adversely affect wildlife.

Table 12. Wildlife Species Observed Along the Souhegan River during 2005 Site Reconnaissance.

Common Name	Scientific Name	Habitat Observed in
Reptiles and Amphibians		
Green Frog	*Rana clamitans melanota*	Back swamps
Spring Peeper	*Hyla crucifer*	Back swamps, pools
Gray Tree Frog	*Hyla versicolor*	Floodplain pools
Bull Frog	*Rana catesbeiana*	Channel
American Toad	*Bufo a. americanus*	Oxbow, backwater, land
Eastern Painted Turtle	*Chrysemys p. picta*	Channel, oxbow
Wood Turtle	*Clemmys insculpta*	Channel
Mammals		
Eastern Chipmunk	*Tamias striatus*	Riparian edge
Red Squirrel	*Tamiasciurus hudsonicus*	Riparian edge
Mink	*Mustela vison.*	Riverbank
Muskrat	*Ondatra zibethicus*	Channel, oxbow
Raccoon	*Procyon lotor*	Oxbow, bank
Beaver	*Castor Canadensis*	Oxbow, bank
White-tailed Deer	*Odocoileus virginianus*	Oxbow, floodplain

Table 12 (cont.). Wildlife Species Observed Along the Souhegan River during 2005 Site Reconnaissance.

Birds		
Common Name	**Scientific Name**	**Habitat Observed in**
Great Blue Heron	*Ardea herodias*	Oxbow, Bank
Canada Goose	*Branta Canadensis*	Channel
Mallard	*Anas platyrhynchos*	Channel
Green-winged Teal	*Anas crecca*	Channel
Common Merganser	*Mergus merganser*	Channel
Double-crested Cormorant	*Phalacrocorax auritus*	Channel
Osprey	Pandion haliaetus	Channel, floodplain
Ruffed Grouse	*Bonasa umbellus*	Floodplain field
Spotted Sandpiper	*Actitis macularia*	Gravel bars
Mourning Dove	*Zenaida macroura*	Floodplain
Black-billed Cuckoo	*Coccyzus erythropthalmus*	Floodplain forest
Chimney Swift	*Chaetura pelagica*	Over channel
Belted Kingfisher	*Ceryle alcyon*	Channel
Hairy Woodpecker	*Picoides villosus*	Floodplain forest
Eastern Phoebe	*Sayornis phoebe*	Riparian edge
Eastern Wood Pewee	*Contopus virens*	Floodplain Forest
Great Crested Flycatcher	*Myiarchus crinitus*	Floodplain
Eastern Kingbird	*Tyrannus tyrannus*	Riparian edge
Red-eyed Vireo	*Vireo olivaceus*	Floodplain
Blue Jay	*Cyanocitta cristata*	Floodplain forest
American Crow	*Corvus brachyrhynchos*	Floodplain
Tree Swallow	*Tachycineta bicolor*	Channel
Bank Swallow	*Riparia riparia*	Channel, bank
Black-capped Chickadee	*Poecile atricapilla*	Wooded eastern edge
White-breasted Nuthatch	*Sitta carolinensis*	Floodplain Forest
American Robin	*Turdus migratorius*	Floodplain
Gray Catbird	*Dumetella carolinensis*	Riparian edge
Cedar Waxwing	*Bombycilla cedrorum*	Channel, Riparian edge
Common Yellowthroat	*Geothlypis trichas*	Riparian edge
Northern Waterthrush	*Seiurus noveboracensis*	Channel debris

Table 12 (cont.). Wildlife Species Observed Along the Souhegan River during 2005 Site Reconnaissance.

Birds		
Common Name	**Scientific Name**	**Habitat Observed in**
Black and White Warbler	*Mniotilta varia*	Floodplain
Yellow-rumped Warbler	*Dendroica coronata*	Riparian edge
Chestnut-sided Warbler	*Dendroica pensylvanica*	Floodplain
Prairie Warbler	*Dendroica discolor*	Floodplain
Scarlet Tanager	*Piranga olivacea*	Floodplain
Savannah Sparrow	*Passerculus sandwichensis*	Floodplain field
Song Sparrow	*Melospiza melodia*	Floodplain field
Northern Cardinal	*Cardinalis cardinalis*	Floodplain
Bobolink	*Dolichonyx oryzivorous*	Floodplain field
Red-winged Blackbird	*Agelaius phoeniceus*	Oxbow, back swamp
Common Grackle	*Quiscalus quiscula*	Channel
Baltimore Oriole	*Icterus galbula*	Floodplain
House Finch	*Carpodacus mexicanus*	Floodplain
American Goldfinch	*Carduelis tristis*	Floodplain

VII.) Aquatic and fish life maintenance and enhancement

(See Sections VI and IX).

VIII.) RTE: Fish, wildlife, vegetation, and natural/ecological communities

A. Rare, Threatened, and Endangered Wildlife

Wood Turtle (Clemmys insculpta)

<u>Location and Description</u>

The Wood Turtle is a riparian species of special concern in New Hampshire, found in and near low gradient, slow moving rivers and streams with sand/gravel substrates and densely vegetated shrub and vine borders (Carroll, 1993). Spring through fall, the Wood Turtle moves frequently between land and water. This movement can be hampered by high, steep riverbanks. The steep 5-9 ft banks typical of the low gradient parts of the Souhegan River (Amherst to Merrimack) indicate a possible entrenchment tendency, so this is not ideal Wood Turtle habitat in many locations. In addition, the Wood Turtle is considered intolerant of pollution (DeGraaf and Yamasaki 2001) and there are clear signs of some municipal pollution on almost the entire length of the river (IPUOCR Report). Nevertheless, Wood Turtles have been observed at several locations on the Souhegan River below the Town of Milford.

The Wood Turtle excavates a nest in sandy banks or adjacent farm fields, laying 4 – 18 eggs in late May to early July. Flooding of nests by high summer flows before the hatchlings leave (in August to early October) can cause direct mortality (NHF&G 2005). Sometime in October or November, depending on weather, the Wood Turtle returns to the water until spring and may enter hibernation. Some Wood Turtles return to the same hibernacula each year (Ernst, et al 1994, NHF&G 2005). The Wood Turtle typically hibernates under water in undercut banks or burrows, beaver lodges, deep pools on the river bottom, or under submerged debris piles/logs in the river channel. In Massachusetts, they have been observed hibernating in 0.3 to 0.6 meters of water in flowing streams (Ernst, et al 1994). Some turtles continue to move about in the winter under river ice and show little sign of hibernating (Hanson, pers. com.). Many turtle activities appear to be temperature dependent, and therefore dates vary from year to year. Hibernating turtles are potentially susceptible to injury or death if exposed to ice or below freezing air temperatures after settling into hibernation sites in autumn.

<u>Evaluation Method</u>
Flow requirements for Wood Turtles were determined using the Floodplain Transect Method. This included a topographic survey of the channel and adjacent banks and floodplain; cover type mapping in the selected segment; and development of cross-sections with plant community boundaries and water levels at various flows. Transects R7 S51 T-1 and R8 S59-60 T-1 are representative of Wood Turtle habitat.

<u>Flow Requirements</u>
Water level changes assumed to be adverse to wood turtles are:

- Low winter flows (Dec – Feb) that drop below the November levels, potentially exposing hibernating turtles in stream banks or pools;
- Release of water in June, July, August or September that floods turtle nests in the floodplain; and
- Flow changes that increase water velocity and/or accelerate channel incision.

The median daily streamflow curve for the Souhegan River based on 70 years of data (over a 94-year time period) indicates that water levels are typically lowest in August and September, gradually rising in October and November and remaining fairly stable until rising in March through April. Deviations from the norm have occurred. A review of monthly mean streamflow over this same 70-year data set indicates that mean December flows were at least 10% lower than mean November flows in 15 of 70 years (21%). Mean December flows were at least 30% lower than mean November flows in eight of 70 years (11%), and in four of these years there was a further drop of at least 10% monthly streamflow in January to well-below the monthly mean. In almost all cases, the mean winter flows were still well above the mean August flow of 78.1 cfs for this period of record, so channel pools and deeper bank hibernacula would still be submerged. If the WMP considers a management strategy that would regularly reduce winter flows below the October/November mean flows of any given year, then winter minimum flow needs for this species will be further evaluated.

Based on observed flooding on April 5, 2005 at Transects in Reaches 7 and 8, flows of 2,000 cfs at the Merrimack gage flood the riverbanks and lower floodplain. Flows of 666 cfs in early June were well below the top of the riverbanks. Flows above 1,000 cfs in June, July, August, September, or early October have the potential to flood the lower sand banks and levees in which some turtles may nest. Since the mean daily streamflow in the Souhegan River for 71 years of record is less than 300 cfs during this period, only an infrequent storm event, dam failure, or planned release would likely cause such a flow. Controllable flows above 1,000 cfs should be avoided during this time period.

Fowlers Toad (*Bufo fowleri*)

Location and Description

Historical records of the rare Fowler's Toad include several locations in Amherst along the Souhegan River, and although this species was not observed during the field investigation, suitable habitat is present. The Fowler's Toad prefers sandy outwash soils. As with the common American Toad (*Bufo americanus*) which was observed in these locations and further downstream, Fowler's Toads are water dependent for breeding, eggs, and larval stage, and would likely use the same shallow, still margins of the Souhegan River in which American Toad tadpoles were observed, although breeding in other water bodies is also possible. Reduction in flows that expose the shallow river margins, backwaters, and oxbows during larval development may strand and eliminate cohorts of toad tadpoles. Fowlers Toad breeds from late May to August, about one month later than American Toads, with tadpoles transforming 6 to 8 weeks later (generally midsummer) (Degraaf and Yamasaki 2000).

Evaluation Method

Flow requirements for the Fowlers Toad were determined using the Floodplain Transect Method. This included a topographic survey of the channel, adjacent banks, backwaters, oxbows, and floodplain; cover type mapping in the selected segment; and development of cross-sections with plant community boundaries and water levels at various flows. Sites 8 and 10 have backwaters and oxbow marshes which are represented on Floodplain Transects R7 S49-50 T-2 and R8 S61 T-2 (Figures ___). In addition, the MesoHABSIM model figures were consulted to identify which oxbows and backwaters were drained at selected target flows.

Flow Requirements

Critical water levels for Fowler's and American Toads are assumed to include:

- Standing water at least 3 inches deep (0.25 feet) in backwaters and oxbow marshes (that were flooded during May and June) until mid-August.

The required flow will be different for each potential breeding area, since the oxbow and backwater connections to the river vary in elevation. Based on the observed water levels at cross-sections and MesoHABSIM data from Transects at R7 S50 and R8 S61, flows between 400 and 600 cfs at the Merrimack Gauge in spring would fill the small backwaters located on these transects that do or could serve as breeding pools. Flows above 30 cfs (based on the MesoHABSIM site maps would maintain standing water in at least some of the oxbow marshes that serve as breeding areas.

Pied-Billed Grebe (*Podolymbus podiceps*)

The State-endangered Pied-Billed Grebe was reported from the Amherst Country Club. This species was not observed during the field visit June 28-30, 2004. Preferred habitat is densely vegetated emergent and deep marsh interspersed with open water that is more than 12 acres in size (Degraaf and Yamasaki 2000; Banner 1998). Specific needs of the Pied-billed Grebe are that standing water must always be present, so to the extent that such a marsh is dependent on river flow, this marsh bird species would be flow dependent. A preliminary inspection of aerial photos and NWI maps of the Souhegan River floodplain indicates that there are no marshes of this size within 500 feet of the Souhegan River. It is unlikely therefore, that flow-dependent breeding habitat for the Pied-billed Grebe is present in the project area.

Osprey (*Pandion haliaetus*)

The Osprey is a State-threatened bird-of-prey observed foraging over the fish hatchery in Milford and over the river during the field survey, and reported from the Amherst Country Club. The closest known New Hampshire osprey nest to the hatchery is at Lake Massabesic in Auburn/Manchester (NH Fish & Game website), which is well beyond the approximate 7 mile maximum foraging range reported for ospreys (Vana-Miller 1987). Ospreys observed along the Souhegan River in summer could be transient individuals. Ospreys consume primarily fish from clear, unobstructed water bodies. They dive up to 3 feet into the water, and are most likely to feed in the pools and reservoirs, although they may take fish with their feet in more shallow areas. Only changes in flow that eliminate pools, reduce fish abundance, increase turbidity, or increase aquatic plant cover are likely to affect Ospreys. Flows that are protective of a healthy fish community will be protective of this species.

Common Loon (*Gavia immer*)

The Common Loon was reported from the Amherst Country Club, although it is unlikely to be nesting along the river. This State–threatened bird could be using the Souhegan River seasonally to forage for fish, its primary food. The Souhegan River is not likely to be a primary habitat for the Common Loon, but foraging opportunities for loons would be indirectly affected by changes in flow as for the Osprey. Flows that are protective of a healthy fish community will be protective of this species.

B. Rare, Threatened, and Endangered Plants

Long's Bitter Cress (*Cardamine longii* Fern.)

Long's Bitter Cress is an obligate aquatic plant. If present in the project area, it is likely to be flow dependent. Consultation with Dan Sperduto of the Natural Heritage Inventory indicates that this is typically an estuarine species, and the record for Greenville may in fact be an error. It is more likely that the community that the record is for was Greenland. Nor further evaluation for this species is proposed.

Wild Garlic (*Allium canadense*)

Wild Garlic (*Allium canadense*) is a Facultative Upland plant on the State-Threatened List in NH with a State Rank of 1 (imperiled because of rarity (generally less than six occurrences) or other factors demonstrably make it very vulnerable to extinction). An historical record exists for the Town of Merrimack, but the location is unknown and may not be within Souhegan watershed. In Maine, the habitat for this species is described as usually found in rich, wooded bottomland hardwoods, in alluvial soils near streams (Maine Department of Conservation, Natural Heritage Program Biological and Conservation Database 2004). Magee and Ahles (1999) describe its habitat in New England as low wet woods and thickets, and rich woods. Though little information was available about the habitat of wild garlic in Merrimack, its wetland status and habitat information suggest it occurs on the upper terraces of streams and rivers. These terraces are typically affected by infrequent flooding events (often 10-year storms or greater), and so may be somewhat dependent on periodic scouring for survival. It was therefore considered flow-dependent on higher flows. If water management alternatives considered in the Water Management Plan affect high flows, then potential impacts to this IPUOCR will be addressed in the WMP.

Wild Senna (*Cassia hebecarpa*)

There are historical records of the State Endangered Wild Senna in three of the towns along the Souhegan River as well as a more recent record from that was confirmed during field investigations. The colony observed was located well above summer water levels, and both above and below flood elevations. This area remains without significant canopy cover due in part to bank flooding and in part to roadside maintenance. The New England Wildflower Society (Clark, 2000) reports that typical habitat for this species includes disturbed habitats (roadsides, fields, and edges of streams), often in damp or alluvial soils. Wild Senna is classified as a Facultative species in New England, which means it is equally likely to be found in uplands and wetlands. This plant may be partially dependent on floods to maintain canopy openings and for seed dispersal, but is not dependent on low or average flows. If water management alternatives considered in the Water Management Plan affect high flows, then potential impacts to this IPUOCR will be addressed in the WMP.

C. Natural Communities

The New Hampshire Natural Heritage Bureau (NHNHB) mapped several Natural Communities considered worthy of protection along the Souhegan River. Precise locations of rare or vulnerable elements in these Natural Communities and other elements identified by the NHNHB as sensitive or rare are not provided in this report; rather the general setting as it relates to river flow is described. Plant nomenclature follows Magee and Ahles 1999.

High Energy Riverbank (Twisted Sedge (*Carex torta*) Low Riverbank and Fern Glade)

<u>Location and Description</u>
High Energy Riverbank community is located along portions of the Upper Souhegan River below Greenville. The plant community in the vicinity of the habitat mapped by NHNHB

anchored to the cobbly river margins is the Twisted Sedge Low Riverbank community (S3S4 - rare to locally abundant). This community is found just above the summer water level to an average 26 cm (maximum of 1 meter) above that level (Sperduto and Nichols, 2004). The river margin is scoured by high flows in spring and ice in winter. Transect R1 S6 T1 includes this community as well as an apparent narrow Fern Glade (status unknown) that forms a narrow band on the sand deposits between the Twisted Sedge Low Riverbank and the hemlock-northern hardwood forest terrace above.

In addition to Twisted Sedge, dominant vegetation includes False Nettle (*Boehmeria cylindrica*) and Joe-Pye Weed (*Eupatorium maculatum*). The most common plants in the fern glade are Interrupted Fern (*Osmunda claytoniana*), New York Fern (*Thelypteris noveboracensis*), Sphagnum Moss and other Bryophytes.

<u>Evaluation Method</u>
Flow requirements for the High Energy Riverbank Community were determined using the Floodplain Transect Method. This included a topographic survey of the channel and adjacent banks and floodplain; cover type mapping in the selected segment; and development of cross-sections with plant community boundaries and water levels at various flows. Transect R1 S6 T1 represents this community.

<u>Flow Requirements</u>
These communities are adapted to daily and seasonal fluctuations in water levels, but permanent alterations to these plant communities could result from:

- Consistent reductions of summer low flows with no other seasonal changes, which could expand the Twisted Sedge Low Riverbank community downgradient;
- Consistent reductions in spring flood levels, ice scour and summer flows, which could alter plant composition in the Low Riverbank Community and allow woody invasion of the Fern Glade.

Median August flow at Site 1, to which the current vegetation is apparently well adapted, is approximately 6.8 cfs as derived from the relationship between the USGS station at the Merrimack and the concurrent measured flows at Site 1. A flow of 7.3 cfs was measured at Site 1 in August 2005, which was a relatively wet month. A consistent decrease in summer low water levels would likely expose additional cobble substrate, potentially allowing the expansion of the Twisted Sedge Low Riverbank Community into the channel. The upper edge of the Twisted Sedge low Riverbank community would still be within 1 meter of the summer water level, and would presumably be maintained by spring floods and winter ice scour, as would the Fern Glade. The potential increase in Twisted Sedge low Riverbank area associated with summer flow reductions, extrapolating the transect data (Figure __) to an estimated 26,000 linear feet of riverbank on which it is found is approximately 3.6 acres (a potential overestimate).

Reductions in flows that also decrease the extent of annual spring highs and ice scour would perhaps allow a greater variety of herbaceous plants to become established in the lower channel, shifting the Twisted Sedge cover type to a more diverse association of herbaceous plants and possibly shrubs, and may allow woody plants to develop where the Fern Glade is currently. Based on field observations of inundation, a reduction of winter and spring flows at Site 1 below approximately 100 cfs would eliminate scouring of the Twisted Sedge community (this corresponds to a flow of 500 cfs at the Souhegan Gauge at the Merrimack gage). The mean of monthly streamflow at the Merrimack Gauge exceeds 500 cfs in March and April (over 70 years of record). There is an estimated 10 acres of Twisted Sedge Community and an estimated 2.4 acres of Fern Glade (assuming it is present only along the 13,000 feet of Site 1 with a well-shaded southern bank) that would be affected by winter/spring flow reductions.

Southern New England Floodplain Forest: Silver Maple *(Acer saccharinum)* Floodplain ForestLocation and Description

Within the Towns of Amherst and Merrimack, in the lower gradient portion of the Souhegan River, Silver Maple Floodplain Forests typical of medium and large rivers in the state were observed. The specific community present, the Silver Maple-False Nettle-Sensitive Fern variant (Figure), is ranked S2 as imperiled state-wide due to rarity, and differs from the Silver Maple Floodplain Forests along the Connecticut River in having greater ground cover diversity, lower soil pH, sandier soil texture, and greater flooding duration and disturbance. The NHNHB mapped one such community along the banks of the Souhegan River in Merrimack. Smaller versions of this community are represented at Sites 8 and 10.

<u>Evaluation Method</u>

Silver Maple Floodplain Forests were mapped using the Floodplain Transect Method. This included a topographic survey of the channel and adjacent banks and floodplain; cover type mapping in the selected segment; and development of cross-sections with plant community boundaries and water levels at various flows. This community is represented on Floodplain Transects R7 S49-50 T1 and T2 and R8 S61 T1 (Figures __ to __). If water management alternatives considered in the Water Management Plan affect high flows and reduce the frequency, duration, or lateral extent of high flows, then potential impacts to this IPUOCR (and associated IPUOCRs, such as Wild Garlic) will be addressed in the WMP.

<u>Flow Requirements</u>

This low floodplain communitydepends on periodic (every 1-3 years or more frequently) flooding and scouring to provide nutrients and bare soil for seedling regeneration, and reduce competition from flood-intolerant plant species. The 2-year return interval flood is approximately 2,683 cfs (at Merrimack Gage). Flooding of these areas occurred in April and October of 2005 with flows as low as 2,000 cfs. During the rest of the growing season, this community has a mesic moisture regime. This community is not dependent on low flows.

Southern New England Floodplain Forest: Sycamore (*Platanus occidentalis*) Floodplain Forest

<u>Location and Description</u>

A Sycamore Floodplain Forest not mapped by the NHNHB is located on an island and floodplain terrace in the Upper Souhegan River. Such communities are ranked as state-imperiled and rare (S1), and are characteristically found on cobbly substrates with flashy streamflow (Sperduto and Nichols, 2004). Some of the other plants considered characteristic of this community were also observed, such as Sugar Maple (*Acer saccharinum*), Bitternut Hickory (*Carya cordiformis*) and Jumpseed (*Polygonum virginiana*). However, the understory was almost pure Sugar Maple, and several plant species considered invasive were common, including Japanese Bamboo (*Polygonum cuspidatum*) and Purple Loosestrife (*Lythrum salicaria*) along the river edge and Honeysuckle (*Lonicera* sp.) and Asian Bittersweet (*Celastrus orbiculata*) in the higher locations.

<u>Evaluation Method</u>
The Sycamore Floodplain Forest was mapped using the Floodplain Transect Method. This included a topographic survey of the channel and adjacent banks and floodplain; cover type mapping in the selected segment; and development of cross-sections with plant community boundaries and water levels at various flows. This community is represented on Floodplain Transect R3 S28 (Figures __ and __). If water management alternatives considered in the WMP affect high flows, then potential impacts to this IPUOCR will be addressed in the WMP.

<u>Flow Requirements</u>
As with other low floodplain communities, the Sycamore Floodplain Forest is dependent on periodic (every one to three years) flooding and scouring to provide nutrients and reduce competition from flood-intolerant plant species. Low flows are less critical. The 2-year return interval flood is 2,683 cfs (at Merrimack Gage). Flows of 2,000 to 3,000 cfs recorded in April of 2005 that flooded the Silver Maple Floodplain Forest downstream on the Souhegan River did not appear to flood much of the Sycamore island. The abundance of Sugar Maple seedlings and saplings in the understory over most of the stand indicates that the Sycamore canopy (Figure) may eventually be replaced by Sugar Maple. Sugar Maple is generally found on mid level or higher floodplain terraces (Sperduto and Nichols 2004; Nislow et al. 2002). Several young Sycamores were observed where flood flows scour the river edge indicating continued Sycamore regeneration in areas of frequent flooding. It is possible that the flood frequency in effect when the canopy vegetation was established has been reduced to that of a higher floodplain terrace, which may be related to upstream dam construction and channelization.

Oxbow/Backwater Marsh

<u>Location and Description</u>

Oxbow and backwater marshes are present along the low-gradient portions of the Souhegan below the Town of Milford in Amherst and Merrimack. These marshes are typically in old meander scars or behind natural levees partially filled in with sediments and therefore often shallower than the adjacent river and connected to it through outlets that may be constricted. Marshes develop only in the oxbows and backwaters sufficiently wide to allow full sun exposure; otherwise they are floodplain pools with canopy cover. The NHNHB did not provide maps of these habitats, but they are ranked S3 for rare and/or local in the State or vulnerable for other reasons.

Marsh vegetation is generally well adapted to short-term water level fluctuations, but susceptible to drowning or desiccation during prolonged floods or droughts. Concentric rings of vegetation were commonly observed to correspond to the water level gradient, with Reed Canary Grass (*Phalaris arundinacea*) and Purple Loosestrife on the highest edges; Water Parsnip (*Sium suave*), Rice Cutgrass (*Leersia oryzoides*), Buttonbush (*Cephalanthus occidentalis*), Three-way Sedge (*Dulichium arundinaceum*) and Spikerush (*Eleocharis* sp.) below that; Arrowhead (*Sagittaria latifolia*), Pickerelweed (*Pontederia cordata*), Burreed (*Sparganium* sp.) and Mild Water Pepper (*Polygonum hydropiperoides*) as the deepest emergents; and Waterweed (*Eleodea Canadensis*), Coontail (*ceratophyllum demersum*), and Yellow Water Lily (*Nuphar lutea*) as submerged and floating-leaved aquatics in the deepest vegetated zone.

The marshes typically fill in spring as the lower floodplain floods, draining slowly during the summer months until only the deeper marshes contain standing water, and surface connections to the river may be temporarily lost. Since floodplains are dynamic, both water levels and the arrangement of sediments and plants are always changing. The oxbow marshes observed on the Souhegan vary in their stability and flow dependence.

For example, the oxbow marsh at Site 8 included three marsh basins with raised sediment deposits between them. These marshes fill in spring as the floodplain floods. As water levels drop during the typical summer, the basins farthest from the river are reduced to small, disconnected pools surrounded by dense vegetation. The basin closest to the river drains more completely as river levels drop below its outlet elevation. This basin is therefore more dependent on low river flows than the other basins. The oxbow marsh at Site 10 has a deeper channel connection directly to the Souhegan River, and would drain more completely but at lower flows. In contrast, an emergent/shrub back swamp at Site 10 has a beaver dam at its outlet, and water levels remained relatively constant throughout the growing season regardless of River flows. The hydrology and vegetation may change when the dam falls into disrepair, a likely natural cycle along a river.

Evaluation Method

Flow requirements for the Oxbow and Backwater Marshes were determined using the Floodplain Transect Method. This included a topographic survey of the channel, adjacent banks, marshes and floodplain; cover type mapping in the selected segment; and development of cross-sections with plant community boundaries and water levels at various flows. Sites 8 and 10 have oxbow marshes, which are represented on Floodplain Transects R7 S49-50 T-2 and R8 S61 T-2 (Figures ___). We attempted to extrapolate this information to the entire lower Souhegan River (below Milford) based on digitized National Wetland Inventory mapping, by querying the area of different wetland types within 500 feet (includes most floodplain areas) of the lower Souhegan River (except those identified as having beaver modified hydrology). In addition, the MesoHABSIM model figures were consulted to identify which oxbows and backwaters were drained at selected target flows.

Flow Requirements

The following general long-term conditions were considered necessary to maintain the approximate quantity and distribution of marsh vegetation in the oxbows/backwaters:

- high spring flows to fill the marshes;
- slowly declining water levels May through September;
- sufficient water May through September to prevent rhizome desiccation.

Based on the floodplain cross sections at Sites 8 and 10, it was determined that should summer water levels be permanently reduced below those observed in August 2005 (31 to 47 cfs) for the entire summer (June-September), the emergent marshes with direct river connections would be partially dewatered, causing vegetation stress and over the long term, a substantial reduction in aquatic bed and deep emergent habitat and an increase in forest, shrub and shallow emergents. Further reductions in flow below these levels for the entire growing season (including lack of spring flooding) could also reduce overall wetland acreage. These effects could also occur if the oxbows fail to fill in spring, which would be addressed if the WMP proposes altering high flows.

The potential shifts in cover type areas on the transects were calculated from the measured community widths on the transects and cover type maps. Extrapolating this information to the entire lower Souhegan River using NWI data, 100% of the total area of aquatic bed oxbow wetlands (0.12 acres) would be lost; the 11.42 acres of forested wetlands on the lower floodplain terrace would increase by approximately 5 acres (45%); and the 6.39 acres of emergent wetlands could increase or decrease, depending on landscape position. This numerical extrapolation is somewhat flawed, given that:

- each marsh has a unique river connection and landscape position that may make it more or less flow dependent than the evaluated marshes;
- NWI maps are not as accurate as on the ground surveys;
- some of the wetlands queried are probably not oxbows, but may be associated with tributaries or back swamps; and
- small wetland vegetation increases in shallow channel margins may partially offset losses in oxbows.

The general assumptions about changes in cover types are relevant, and would be expressed differently at each particular location. If water management alternatives considered in the WMP affect high flows, then additional potential impacts to the Oxbow Marsh IPUOCR will be addressed in the WMP.

IX.) Environmental/Fish Habitat

Target Fish Community Development

The status of the Souhegan River fish community was evaluated using the Target Fish Community (TFC) approach developed by Bain and Meixler (2000). Two separate target fish communities were developed for the Souhegan River using a GIS based method of selecting quality rivers that were physically and zoogeographically similar to the upper and lower Souhegan River. Fish data from these rivers were then used to compute the expected proportions of fish within the Target Fish Communities using the rank-weighted technique developed by Bain and Meixler (2000). The existing fish faunas of the Souhegan River were then compared to the TFC using a percent model affinity procedure developed by Novak and Bode (1992) to evaluate the status of the fish faunas within the upper and lower portions of the Souhegan River. For more detail on the upper and lower TFC development process refer to Appendix 6.

Upper Souhegan River Target Fish Community

The upper Souhegan River TFC was created using fish collection data from eleven quality reference rivers as described in Appendix 6. The resulting community of 18 species was diverse but dominated by fluvial species. The ten most abundant species in the TFC were blacknose dace (29%), longnose dace (15%), common shiner (10%), white sucker (7%), fallfish (6%), slimy sculpin (5%), Eastern brook trout (4%), longnose sucker (4%), redbreast sunfish (3%), and Atlantic salmon (3%). The remaining species consisted of brown bullhead, creek chub, yellow perch, pumpkinseed sunfish, golden shiner, Eastern chain pickerel, spottail shiner, and American eel, and accounted for a combined total of 14% of the expected community with individual proportions ranging between 1% and 2%.

Lower Souhegan River Target Fish Community

The lower Souhegan River TFC was created using fish collection data from five quality lower reference rivers as described in Appendix 6. The TFC was as equally diverse as the upper TFC. It had 17 species and was also dominated by fluvial species. The ten most abundant species in the lower TFC were white sucker (30%), fallfish (15%), common shiner (10%), blacknose dace (8%), longnose dace (6%), yellow perch (5%), pumpkinseed sunfish (4%), brown bullhead (3%), tessellated darter (3%), and Eastern chain pickerel (3%). The remaining species, redbreast sunfish, golden shiner, creek chubsucker, American eel, spottail shiner, and Eastern brook trout, account for a combined total of 12% of the expected community with individual proportions ranging between 1% and 2%.

Fish and Invertebrate Sampling

In an effort to evaluate the status of the instream fauna of the Souhegan River, instream surveys were conducted on the fish and invertebrate communities of the upper and lower river.

In July and August 2005, fish were sampled using pre-positioned electrofishing grids (Bain, 1985) in the upper river (Reaches 1-3) and within suitable (less that 1 m water depth) sections of representative site 7 (Reach 5) on the lower river. The majority of the lower river however, consisted of depths unsuitable for this method of electrofishing and was surveyed through underwater observations of fish while snorkeling. Snorkel surveys occurred in August and September 2005 within previously selected hydromorphologic units or habitat types that were, as a whole, representative of each sampling site and the lower segment of the river.

Evaluation of the invertebrate community within the Souhegan River consisted of a freshwater mussel survey and sampling of aquatic insects to identify individual species of mussels and odonates within the river. The desire was to create an experimental model capable of identifying suitable habitat and instream flow requirements for these organisms. See Appendix 7 for more detail.

Existing Fish Community

Upper Souhegan River fish community

The existing fish community of the upper segment of the Souhegan River, as sampled in the summer of 2005, was dominated by blacknose dace (55%), longnose dace (25%), fallfish (6%), common shiner (5%), white sucker (3%), yellow perch (2%), largemouth bass (2%), Atlantic salmon (1%). The Upper Souhegan fish community consisted of native fluvial species (94%), with a small proportion of macrohabitat generalists (5%). Pumpkinseed, golden shiner, and brown trout, combined, comprised the remaining 1% of the community. A total of 11 different fish species were sampled in the upper segment of the Souhegan River, 9 of which were native. The only two non-native fish species sampled in the upper Souhegan, largemouth bass and brown trout, accounted for less than 3% of the community.

Lower Souhegan River fish community

The existing fish community of the Lower Souhegan River, also surveyed in the summer of 2005, was dominated by common shiner (30%), fallfish (20%), blacknose dace (16%), white sucker (13%), redbreast sunfish (13%), longnose dace (4%), largemouth bass (2%) and golden shiner (1%). The lower Souhegan fish community consisted of primarily native fluvial species (84%), with a considerably lesser proportion of macohabitat generalists (16%). Yellow bullhead, brown trout, creek chubsucker, chain pickerel, yellow perch, bluegill, rainbow trout, and pumpkinseed accounted for a combined total of less than 2% of the community. A total of 16 different fish species were sampled in the Lower Souhegan River, 11 of which were native. The five non-native species sampled in the Lower Souhegan, largemouth bass, yellow bullhead, brown trout, bluegill, and rainbow trout accounted for a combined total of less than 3% of the community.

Existing Invertebrate Community

Upper Souhegan River mussel community

In the fall of 2004 multiple habitat types were surveyed in the Upper Souhegan River. Representative sites 1, 2, 3, 4, and 5 were surveyed with 128 quadrates placed at random locations throughout various hydromorphological unit (HMU) types representative of the upper river. The 2004 survey did not locate any freshwater mussels in any of the habitat units that were sampled.

Lower Souhegan River mussel community

The 2005 mussel survey of the Lower Souhegan River resulted in the location of 71 mussels originating from 27 of the 93 quadrates sampled. The three different species of freshwater mussels that were located and identified during these surveys were triangle floater (*Alasmidonta undulata*) (3%), Eastern elliptio (*Elliptio complanata*) (94%), and creeper (*Strophitus undulatus*) (3%). Densities within a quadrate ranged from 1-14 mussels. The quadrate containing the highest density of mussels (n=14) was located within our representative site 7 which also contained the highest density of mussels found within a site (n=32). Site 7 did not however, exhibit a diversity of species, as all 32 specimens sampled were Eastern elliptio. Triangle floater were found along with Eastern elliptio within representative site 10, and observations of single creeper specimens were found, also along with Eastern elliptio within representative sites 8 and 9. Eastern Elliptio occurred within every representative site of the Lower Souhegan River.

Upper Souhegan River odonate community

Odonate samples were collected from representative sites 1, 2, 3, and 5 on the Upper Souhegan River during the fall of 2004. A total of 52 individuals of the Odonatae family were collected from 34 of the 100 quadrates sampled. Odonates were collected from all representative sites that were sampled. The maximum number of odonates collected from a single quadrate was three. Of the 52 individuals collected, representative site 1 accounted for 29%, site 2 for 28%, site 3 for 31%, and site 5 for only 12% of the total number of odonates collected.

Lower Souhegan River odonate community

Odonate samples were collected from representative sites 6, 7, 8, 9, 10, and 11 on the lower segment of the Souhegan River during the fall of 2005. A total of 60 individuals of the Odonatae family were collected from 33 out of the 93 quadrates sampled. The maximum number of odonates collected from a single quadrate was five. Of the 60 individuals collected, representative site 6 accounted for 22%, site 7 for 30%, site 8 for 12%, site 9 for 20%, site 10 for 13%, and site 11 for 3% of the total number of odonates collected.

Comparison of TFC to the Existing Souhegan River Fish Community

Percent model affinity

Evaluation of the status of the fish fauna in the Souhegan River was accomplished using a direct similarity comparison between the TFC and the Souhegan River fish community as sampled in 2005. This procedure yields values from 0 to 100 to describe the extent to which the Souhegan River fish community is similar to the TFC. The higher the yielded percent model affinity value, the higher the degree of similarity between the communities. These values are calculated as:

$$\text{Percent similarity} = 100 - 0.5\,(\text{Sum}\,|\,\text{target P} - \text{observed P}\,|)$$

where: P = proportions of each species in the community or collection

Under-represented species, over-represented species, and introduced or non-native species within the Souhegan River were also identified based on their relationship to expected proportions identified in the TFC. Additional comparisons were made between the proportions of habitat use classification guilds within the two communities. Similarly, pollution tolerance and thermal regime tolerances classification guilds were compared.

Habitat Use, Pollution Tolerance, Thermal Regime Classification Guilds

The fish species within the TFC and the Souhegan River existing fish communities were organized into specialized habitat use and pollution tolerance classification guilds based on classifications assigned by Bain (2000). Creek chub, fallfish, longnose dace, longnose sucker, and slimy sculpin were reclassified as fluvial specialists in this study, as in previous target fish community studies within this region based on their local habitat use patterns (Lang et al., 2001; Kearns et al., 2005). Fish species were also classified based on their thermal regime specifications. These were assigned based on a review of the literature pertinent to the fishes of the northeast region (Scarola, 1987; Hartel et al. 2002; NAI, 2004; Halliwell et al., 1999).

Upper Souhegan River habitat use guilds

The upper TFC consisted of 67% fluvial specialist, 18% fluvial dependent, and 15% macrohabitat generalist species. The Upper Souhegan River existing fish community consisted of 87% fluvial specialist, 8% fluvial dependent, and 5% macrohabitat generalist species (Figure 11).

Lower Souhegan River habitat use guilds

The lower TFC consisted of 35% fluvial specialist, 42% fluvial dependent, and 23% macrohabitat generalist species. The Lower Souhegan existing fish community was comprised of 41% fluvial specialist, 43% fluvial dependent, and 16% macrohabitat generalist species (Figure 12).

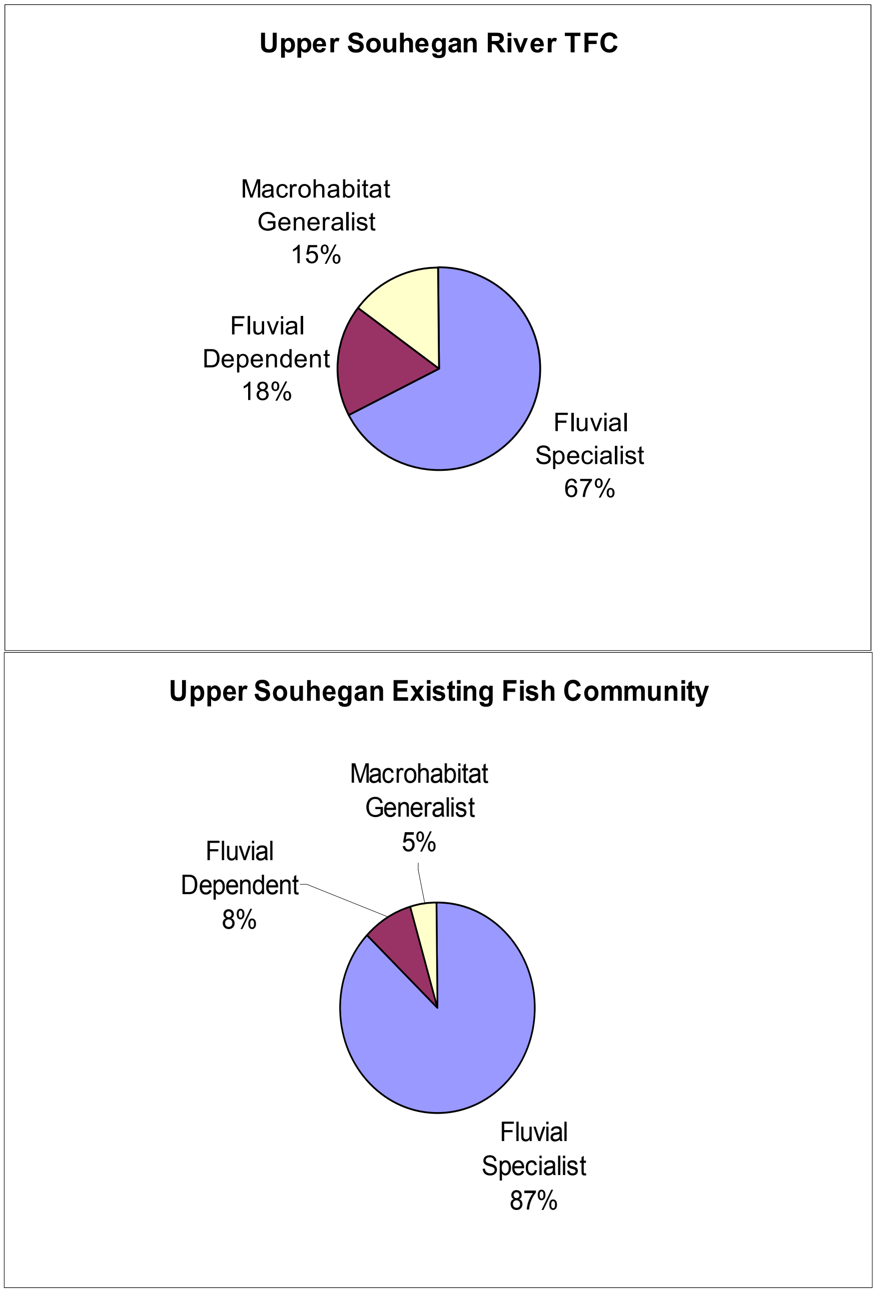


Figure 11. Percentages of Upper Souhegan River TFC and existing fish community species by habitat use classification guilds.

Comparison of Species Within the TFC and the Existing Fish Communities

Differences between proportions of individual species in the TFC and the existing fish communities of the Souhegan River were analyzed to evaluate the status of individual fish species within the river. The analysis of deviations was used to determine fish species that were under-represented, existing in expected proportions, overly abundant, or absent in the Upper Souhegan River. Species with proportions 50% lower than expected were considered underrepresented and species with proportions 30% higher than expected were considered overabundant. The presence of non-native or introduced fish species and their proportion of the existing community were also identified.

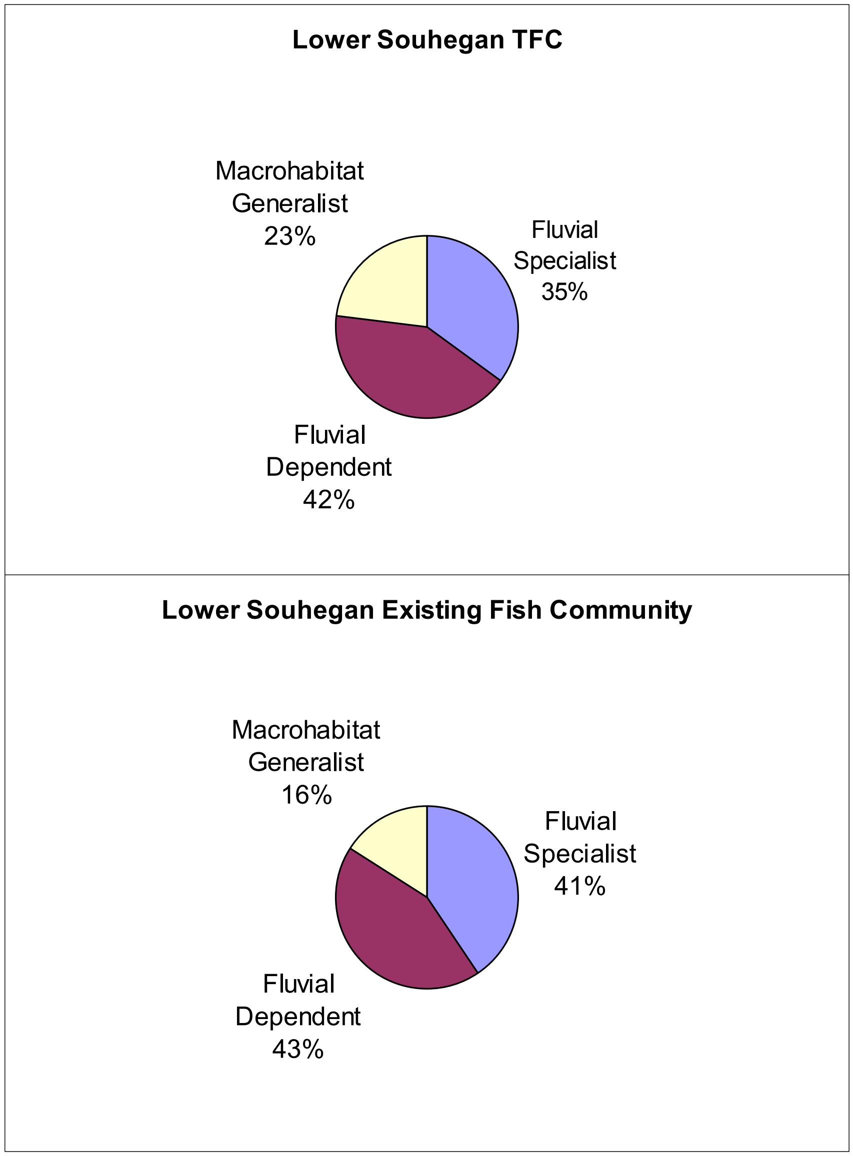


Figure 12. Percentages of Lower Souhegan River TFC and existing fish community species by habitat use classification guilds.

Table 13. Comparison of proportions of fish species between the TFC and Upper Souhegan River existing fish community identifying under-represented, existing as expected, overly abundant, missing, and introduced species in the upper Souhegan River. Native (N) or introduced (I) statuses, fluvial specialist (FS), fluvial dependent (FD), or macrohabitat generalist (MG) habitat use classifications, intolerant (I), moderate (M), or tolerant (T) pollution tolerances, and Cold, Cool, or Cold water thermal regimes are given for each species.

Species	Proportion of Target Fish Community	Proportion of Existing Fish Community	Native or Introduced	Habitat use Classification	Pollution Tolerance	Thermal Regime
Underrepresented native target fish species						
Atlantic salmon	3%	1%	N	FS	I	Cold
Common shiner	10%	5%	N	FD	M	Cool
Golden shiner	2%	<1%	N	MG	T	Cool
Pumpkinseed	2%	<1%	N	MG	M	Warm
White sucker	7%	3%	N	FD	T	Cool
Target fish species recorded as expected						
Fallfish	6%	6%	N	FS	M	Cool
Yellow perch	2%	2%	N	MG	M	Cool
Overly abundant native target fish species						
Blacknose dace	29%	55%	N	FS	T	Cool
Longnose dace	15%	25%	N	FS	M	Cool
Missing native target fish species						
American eel	1%	0%	N	FD	T	Cool
Brown bullhead	2%	0%	N	MG	T	Warm
Chain pickerel	2%	0%	N	MG	M	Warm
Creek chub	2%	0%	N	FS	T	Cool
Eastern brook trout	4%	0%	N	FS	I	Cold
Longnose sucker	4%	0%	N	FS	M	Cold
Redbreast sunfish	3%	0%	N	MG	M	Warm
Slimy sculpin	5%	0%	N	FS	I	Cold
Spottail shiner	1%	0%	N	MG	M	Cool
Introduced species present in the existing fish community						
Brown trout	0%	<1%	I	FD	I	Cool
Largemouth bass	0%	2%	I	MG	M	Warm

* The expected proportion of Atlantic salmon is most likely lower than under natural conditions. The reason is that none of the reference rivers have this species in natural proportions.

Upper Souhegan River species comparison

Atlantic salmon, common shiner, golden shiner, pumkinseed and white sucker were determined to be under-represented in the Upper Souhegan community, while blacknose dace and longnose dace were found in greater abundances than predicted target community proportions. Brown trout and largemouth bass represented the only two non-native or introduced species in the Upper Souhegan fish community (Table 13).

Lower Souhegan River species comparison

In the lower community chain pickerel, creek chub sucker, pumpkinseed, yellow perch and white sucker were found to be under-represented, while blacknose dace, common shiner and redbreast sunfish were considered to be over-represented. Introduced species existing in the Lower Souhegan River were bluegill, brown trout, largemouth bass, rainbow trout, and yellow bullhead (Table 14).

Table 14. Comparison of proportions of fish species between the TFC and Lower Souhegan River existing fish community identifying under-represented, existing as expected, overly abundant, missing, and introduced species in the upper Souhegan River. Native (N) or introduced (I) statuses, fluvial specialist (FS), fluvial dependent (FD), or macrohabitat generalist (MG) habitat use classifications, intolerant (I), moderate (M), or tolerant (T) pollution tolerances, and Cold, Cool, or Cold water thermal regimes are given for each species.

Species	Proportion of Target Fish Community	Proportion of Existing Fish Community	Native or Introduced	Habitat use Classification	Pollution Tolerance	Thermal Regime
Underrepresented native target fish species						
Chain pickerel	3%	<1%	N	MG	M	Warm
Creek chubsucker	2%	<1%	N	FS	I	Cool
Pumpkinseed	4%	<1%	N	MG	M	Warm
Yellow perch	5%	<1%	N	MG	M	Cool
White sucker	31%	13%	N	FD	T	Cool
Target fish species recorded as expected						
Fallfish	15%	20%	N	FS	M	Cool
Golden shiner	2%	1%	N	MG	T	Cool
Longnose dace	6%	4%	N	FS	M	Cool
Overly abundant native target fish species						
Blacknose dace	8%	17%	N	FS	T	Cool
Common shiner	10%	30%	N	FD	M	Cool
Redbreast sunfish	2%	13%	N	MG	M	Warm
Missing native target fish species						
American eel	2%	0%	N	FD	T	Cool
Brown bullhead	3%	0%	N	MG	T	Warm
Eastern brook trout	1%	0%	N	FS	I	Cold
Spottail shiner	2%	0%	N	MG	M	Cool
Tessellated darter	3%	0%	N	FS	M	Cool
Introduced species present in the existing fish community						
Bluegill	NA	<1%	I	MG	T	Warm
Brown trout	NA	<1%	I	FD	I	Cool
Largemouth bass	NA	2%	I	MG	M	Warm
Rainbow trout	NA	<1%	I	FD	I	Cold
Yellow bullhead	NA	<1%	I	MG	T	Warm

Comparison of TFC and Existing Community Species to Souhegan River Suitable Habitat Availability

Habitat suitability criteria were used to determine the proportions of suitable habitat available for Souhegan River fish species (see below). These habitat proportions were then compared to the predicted and existing proportions of fish species for the river to identify instances where habitat may possibly be a limiting factor in the existing proportions of fish species.

Upper Souhegan River

Two species considered as under-represented in the existing fish community, common shiner and white sucker, were found to exist in proportions similar to the proportions of available habitat at the three flow scenarios. These species may be limited by habitat availability on the upper Souhegan River. The habitat increases with flow for brook trout, a species missing from the Souhegan River fish community, existed in considerable proportions at all three flows. Based on this analysis, habitat did not seem to be the primary factor explaining the absence of brook trout from the Upper Souhegan River. Blacknose dace, fallfish, and longnose dace did not appear to be limited by habitat (Figure 13).

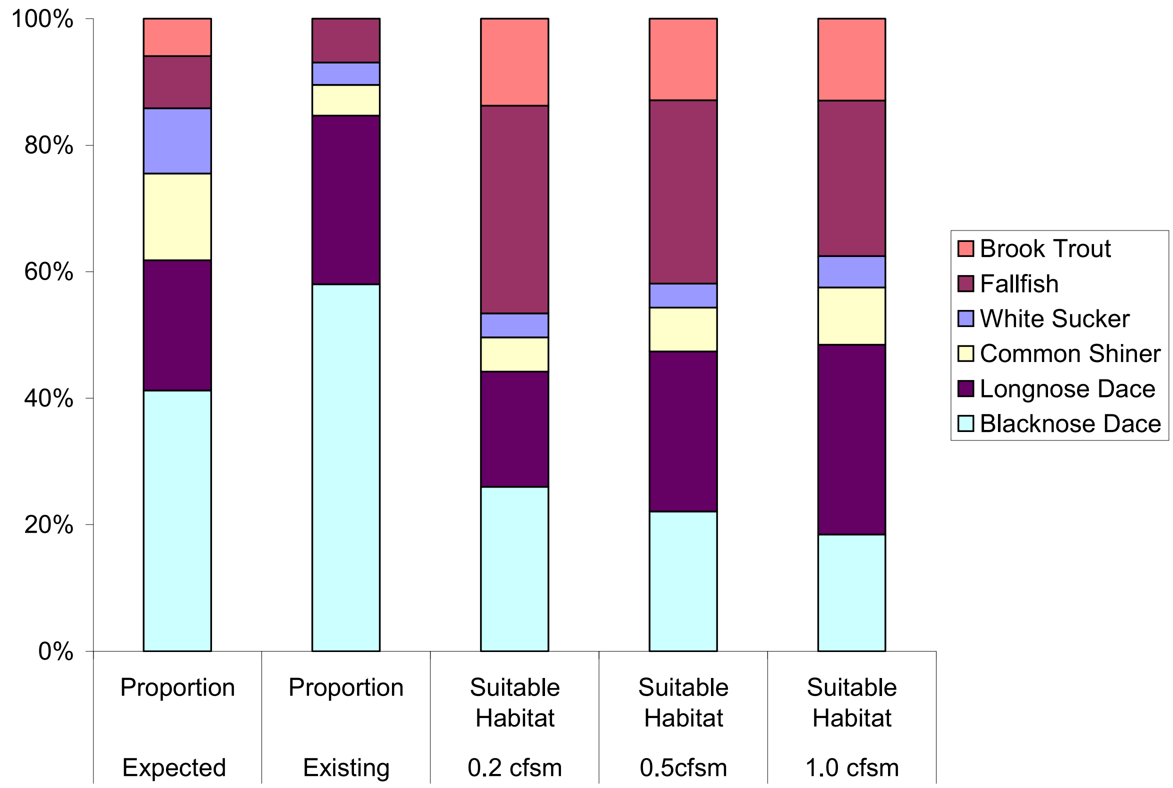


Figure 13. Comparison of proportions of fish species and their suitable habitats for the Upper Souhegan River.

Lower Souhegan River

The only under-represented fluvial species present on the Lower Souhegan River, white sucker, did not appear to be limited by habitat. An appreciable amount of suitable habitat was available for this species on the lower river. Likewise, brook trout, a species missing from the existing fish community of the Lower Souhegan River, seemed to have amounts of suitable habitat sufficient to support expected proportions predicted by the TFC. Conversely, proportions of longnose dace in the lower river could be limited by the amount of suitable habitat available. Blacknose dace, common shiner, and fallfish did not seem to be affected by habitat limitations on the lower Souhegan, as proportions exist in higher or similar abundances to the TFC (Figure 14).

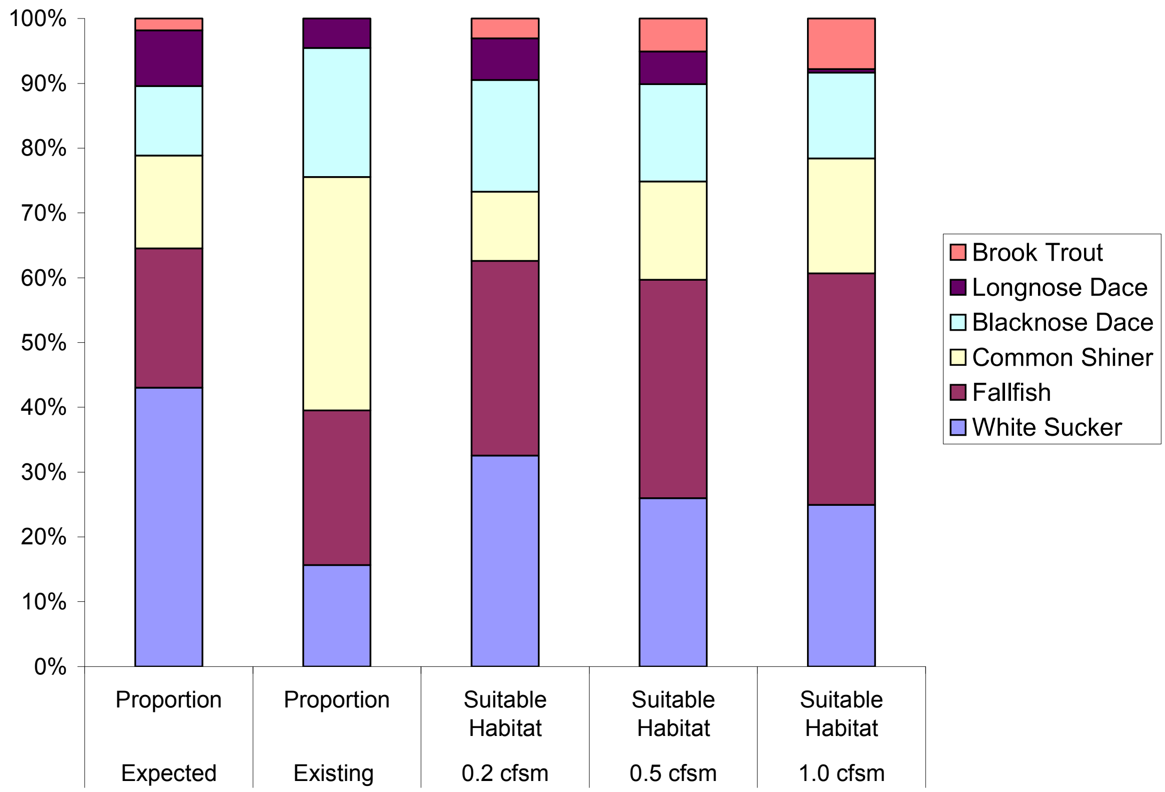


Figure 14. Comparison of proportions of fish species and their suitable habitats for the Lower Souhegan River.

Indicator Species

With the exception of over-wintering and spring flood seasons, the habitat model refers to the habitat used by the actual community present in a bio-period. After analysis of the TFC, for each bio-period, a group of species representing the aquatic community was specified. Hence, the habitat needs for rearing and growth season were represented by a select group of species dominating the TFC. These fish were referred to as generic resident adult fish

(GRAF) and young-of-the-year life stage (YOY). In addition the habitat needs of diadromous species (American eel, juvenile Atlantic salmon), underrepresented fish species (brook trout and slimy sculpin), freshwater mussels, and odonates have been taken into consideration. Those species were referred to as Special Interest Fish and Invertebrates (SIFI). During the spring spawning season the habitat needs of the anadromous Clupeids (American shad, alewife) and resident fauna were analyzed jointly. In the fall season the needs of resident fish were combined with those of the spawning life stage of Atlantic salmon. Habitat models have been developed for all of the above groups to determine the flow sensitivity of their habitat. The species (or species groups) with flow dependent habitat were selected as indicators for a season or bio-period.

Upper and Lower Souhegan indicator species

For the Upper Souhegan species selected to compose the GRAF group consist of longnose dace, blacknose dace, common shiner, fallfish, and white sucker. The slimy sculpin, Atlantic salmon, brook trout, mussels and odonates were selected to create the SIFI group. For Lower Souhegan the same species serve as GRAF. Slimy sculpin is not included in the SIFI group for the lower segment of the river but all other species within the SIFI group for the Upper Souhegan are the same for the Lower Souhegan.

Habitat Suitability Criteria

For each selected species and group of species two types of habitat suitability criteria were employed. For conditions where collection of empirical data was limited or impossible, available literature and professional judgment were used to develop a list of physical criteria associated with suitable habitat for indicator species. For conditions where adequate empirical data existed, these data were used to select criteria associated with habitat suitability and develop a model to identify levels of suitability of the previously mapped mesohabitats of the Souhegan River.

Due to the lack of empirical data for GRAF and SIFI spawning habitat suitability, a literature-based spawning habitat model was developed based on four habitat attributes. The spawning requirements of GRAF species and two SIFI species (Atlantic salmon and American shad) with regard to these four habitat attributes: depth, velocity, choriotop (substrate type), and HMU type, were researched. Criteria, values, and ranges were selected for each attribute that was indicative of suitable spawning habitat for a selected species. A spawning model was then created that would identify suitable spawning habitats for each species based on the presence of selected habitat attributes that meet the requirements of a particular species (Appendix 8).

The empirical set of criteria for R&G (rearing and growth) season had been developed from habitat use data collected in earlier studies for resident adult fish, SIFI and YOY. The fish habitat data collected on the Pomperaug River (196 grids), Eightmile River (350 grids) and Fenton River (500 grids) in Connecticut were analyzed with the help of a multivariate statistical model (logistic regression) to compute the habitat selection criteria for adult resident fish species and SIFI (for details on this method please see Appendix 8). The model selects habitat attributes corresponding with presence and abundance of the species that are then used to calculate probability of presence and high abundance in the surveyed mesohabitats. Unsuitable, suitable, and optimal habitats, corresponding with high probabilities of fish absence, presence, and high abundance, respectively, were distinguished. For YOY habitat, which consists only of shallow margins, empirical criteria developed on the Quinebaug River were applied.

Habitat Data Collection

The surveys of representative sites were repeated three times at conditions representing low summer flows determined by analysis of hydrologic time series obtained from the USGS gage in Merrimack, NH. The range of flows was defined using the Indices of Hydrological Alteration (Richter et al. 1997) between 0.1 cfsm and 1 cfsm. This was also expected to roughly encompass the range of fish behavior associated with low flows. For our three surveys we targeted flows corresponding with 0.1 cfsm, 0.5 cfsm and 1 cfsm (+/- 10%) readings at the Merrimack gage. The actual flows at each site were determined from power law functions obtained from concurrent flow measurements (see Appendix 3).

Mapping

Figure 15 presents the timing and flows during the habitat surveys. The majority of the surveys took place in summer 2005. Three measurements for each site were completed with the exception of site 11. Because of very flashy flow conditions in the Souhegan River during summer 2005, the window of opportunity for mapping of the river at the flows of 1 cfsm was very limited (Figure 15) and therefore site 11 could not be mapped at this flow. Therefore it was decided to limit the length of the Lower Souhegan to the area upstream of Wildcat Falls. The section downstream of Wildcat Falls, represented by site 11, was analyzed separately at the two lower flows only (Appendix 8).

Rating Curves for Sites

The habitat quality in the sites was evaluated using criteria established as described in the previous paragraphs. The habitat suitability for all investigated species was calculated for each HMU, species, and life stage. Subsequently the HMU's were assigned to one of the above categories (unsuitable, suitable, optimal). The relative area of suitable and optimal habitat was determined for each site and flow and converted to habitat rating curves for every species and GRAF. The latter was computed by using the sum of habitats for GRAF species weighted by their expected proportions in the TFC. For species where an optimal habitat model could be established we computed the habitat area by weighting suitable habitat with 25% and optimal with 75% and adding them. For other species only suitable habitat was evaluated. The rating curves for the sites were generalized to Reaches.

To complement the assessment of the status of the fish fauna we also computed the structure (proportions) of habitat available for GRAF in each segment. The comparison with structure of the TFC and XFC allowed us to determine if habitat was potentially a limiting factor in fish abundance, specifically for species with flow sensitive habitats.

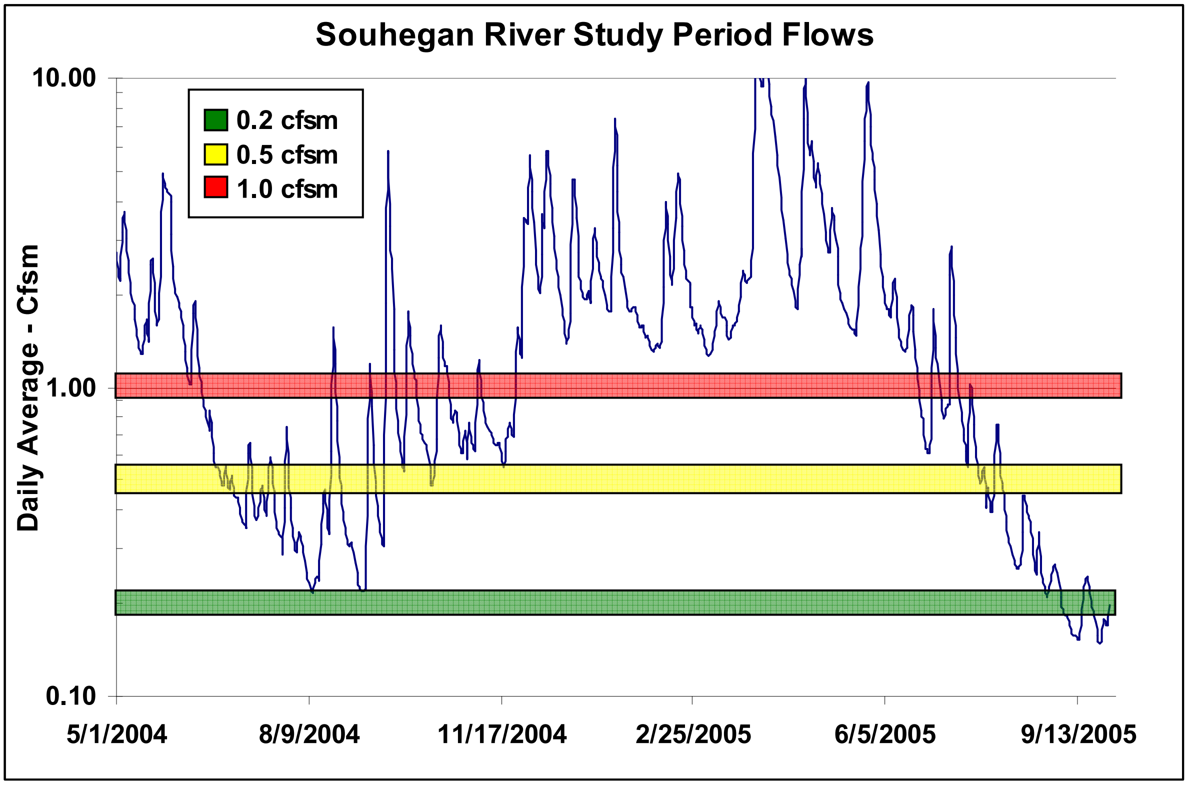


Figure 15. Hydrograph for the USGS stream gage at Wildcat Falls for the duration of the hydromorphological mapping period. The area shaded in green shows the days that the rivers flow was within 10% of 0.2 cfsm. The area shaded in yellow shows the days that the rivers flow was within 10% of 0.5 cfsm. The area shaded in red shows the days that the rivers flow was within 10% of 1.0 cfsm.

Reach 1

Rearing and Growth Bio-period

Atlantic salmon, American eel, slimy sculpin, YOY, and GRAF had increasing habitat area availability with flow until approximately 0.4 cfsm where they then remained stable. Brook trout decreased slightly with flows over 0.25 cfsm, but was largely non-flow dependant. There was no available odonate habitat in this study reach. American eel had the greatest available habitat, reaching 80% at flows over 0.3 cfsm. Atlantic salmon gained the most habitat area, increasing from 0% at 0.1 cfsm to 40% at 0.4 cfsm (Figure 16).

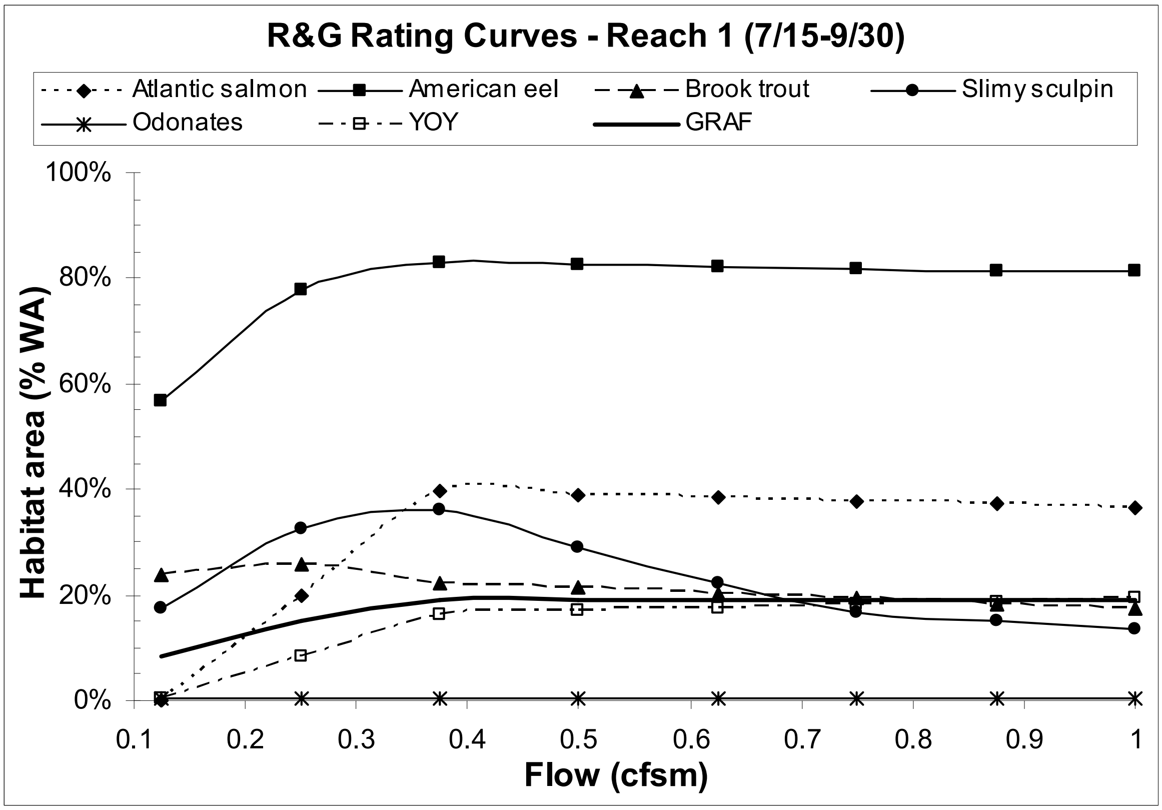


Figure 16. Habitat Rating curves for Reach 1 species during the R&G bio-period.

Spawning

Blacknose dace, common shiner, longnose dace, and GRAF had increasing habitat area availability with flow until around 0.4 cfsm where they then remained stable. Fallfish habitat area decreased slightly with flow, but was largely non-flow dependant. White sucker had the greatest available habitat area, reaching 47% at flows of 0.28 cfsm before slowly decreasing with increasing flows. Longnose dace gained the most habitat area, increasing from 10% at 0.1 cfsm to 23% at 0.4 cfsm (Figure 17).

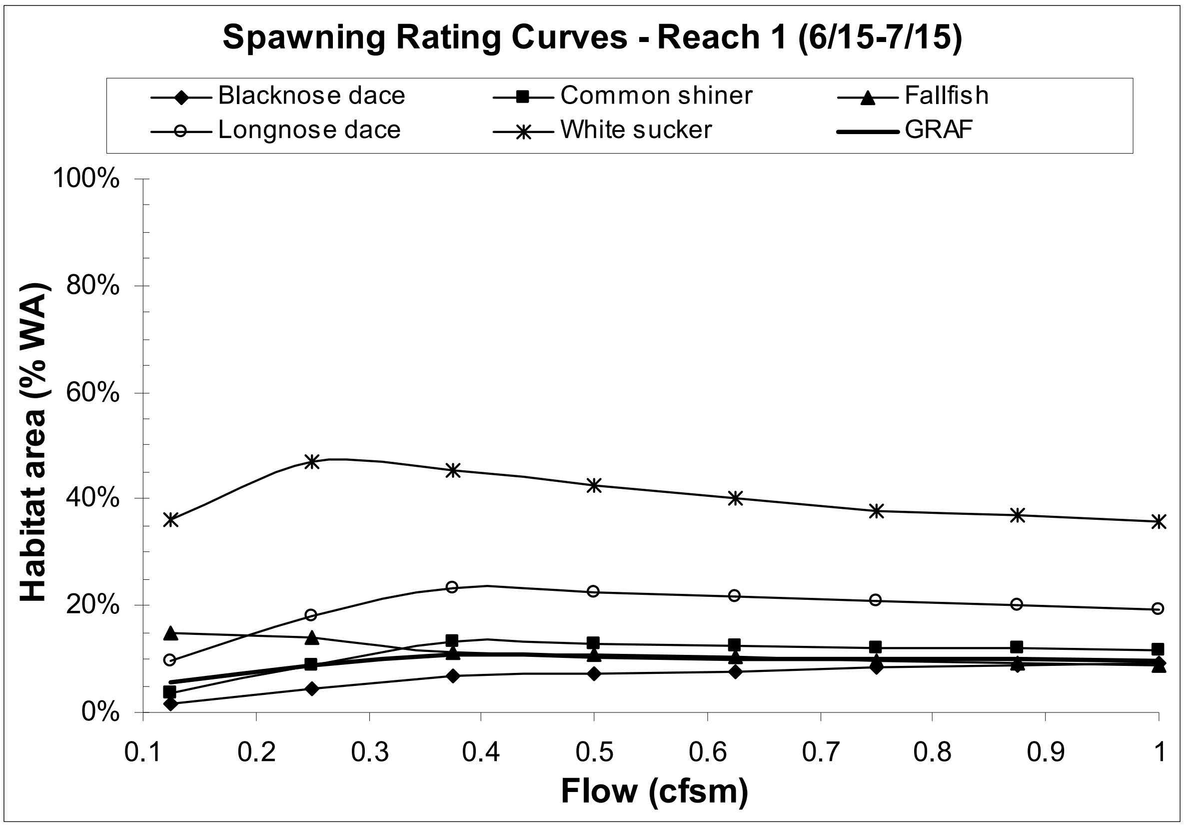


Figure 17. Habitat Rating curves for Reach 1 species during the Spawning bio-period.

Anadromous Spawning

Atlantic salmon and American shad habitat area both decreased slightly with increasing flow from 0.1 to 0.4 cfsm, at which point they each gained habitat area. American shad gained the most habitat area, increasing from 8% at 0.4 cfsm to 35% at 1.0 cfsm (Figure 18).

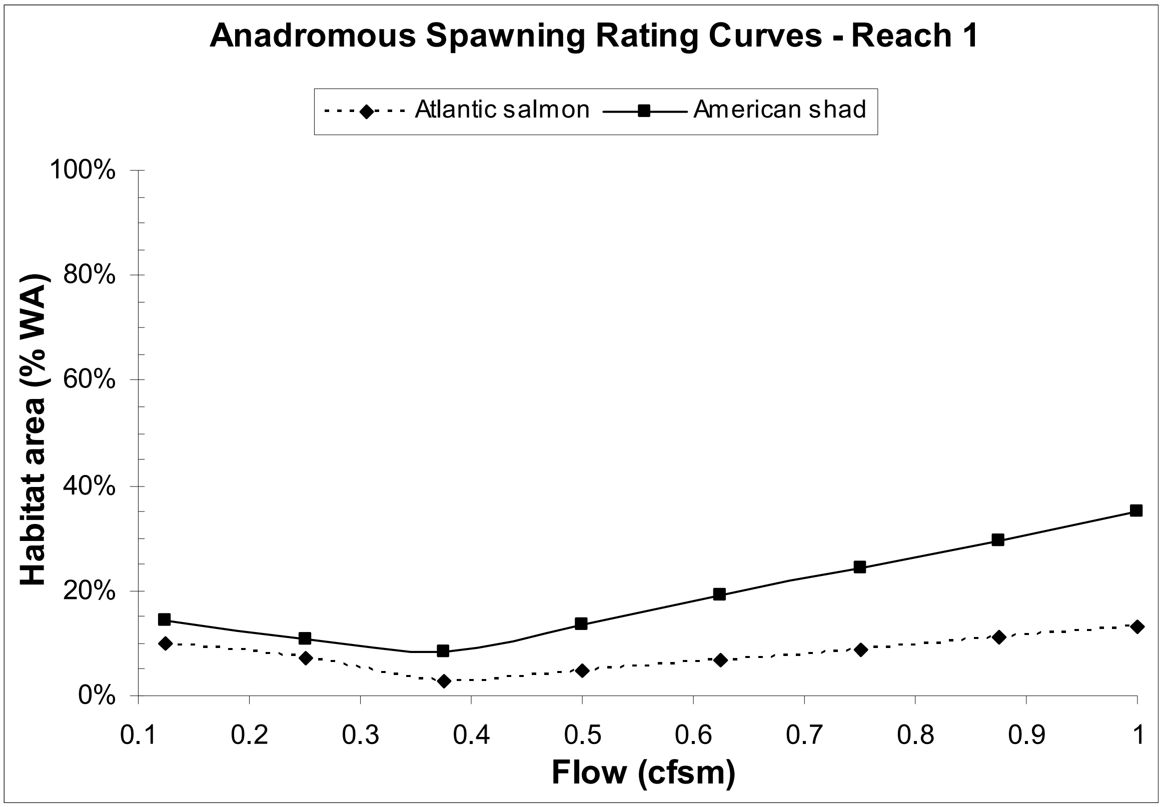


Figure 18. Habitat Rating curves for Atlantic salmon and American shad spawning bio-period in Reach 1.

Reach 2

Rearing and Growth Bio-period

Brook trout, slimy sculpin, odonates, and GRAF had slightly increasing habitat area availability with flow until approximately 0.25 cfsm where they then slowly decreased. Atlantic salmon and YOY had increasing habitat area with flow until around 0.25 cfsm where they remained stable. American eel had the greatest available habitat, starting with 100% at flows of 0.1 cfsm and decreasing to 93% at 1.0 cfsm. Atlantic salmon gained the most habitat area, increasing from 15% at 0.1 cfsm to 35% at 0.25 cfsm (Figure 19).

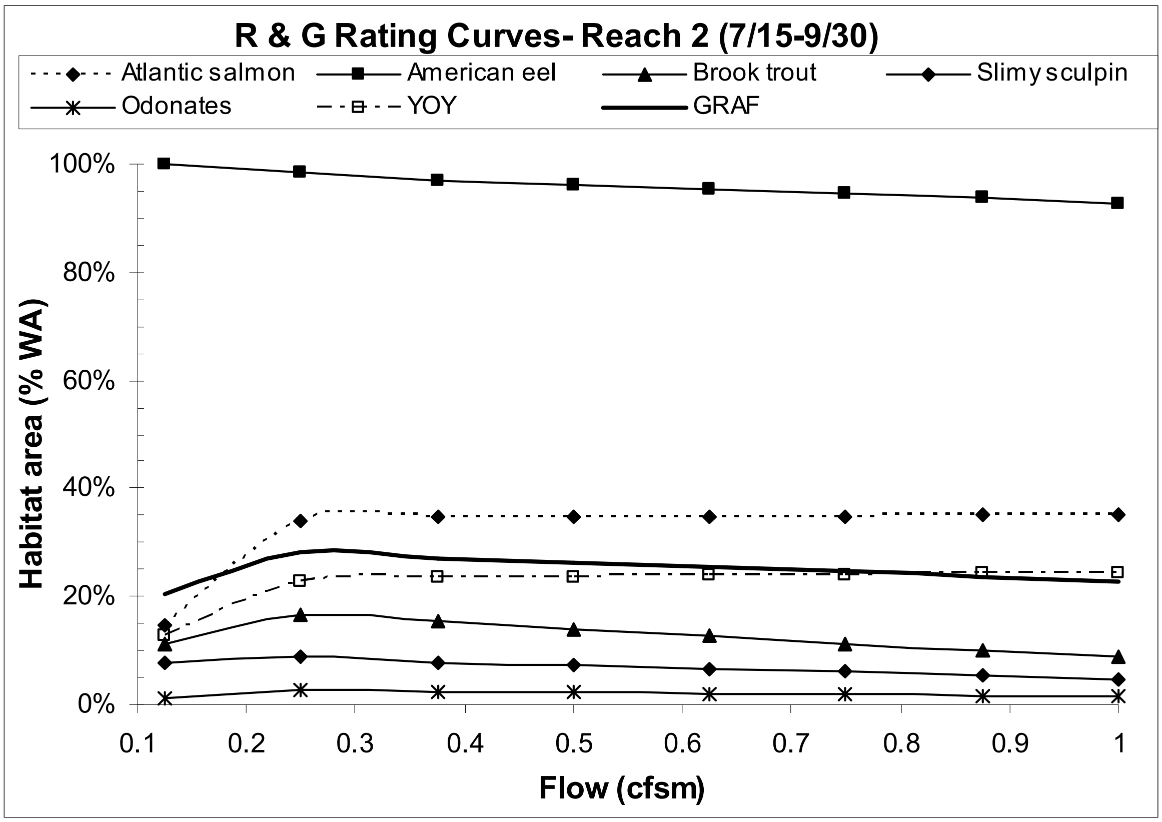


Figure 19. Habitat Rating curves for Reach 2 species during the R&G bio-period.

Spawning

Blacknose dace, common shiner, fallfish, longnose dace, white sucker, and GRAF all had increasing habitat area availability with flow until around 0.3 cfsm where they then decreased slightly with increasing flows. White sucker had the greatest available habitat area, reaching 90% at flows of 0.3 cfsm. White sucker also gained the most habitat area, increasing from 46% at 0.1 cfsm to 90% at 0.3 cfsm (Figure 20).

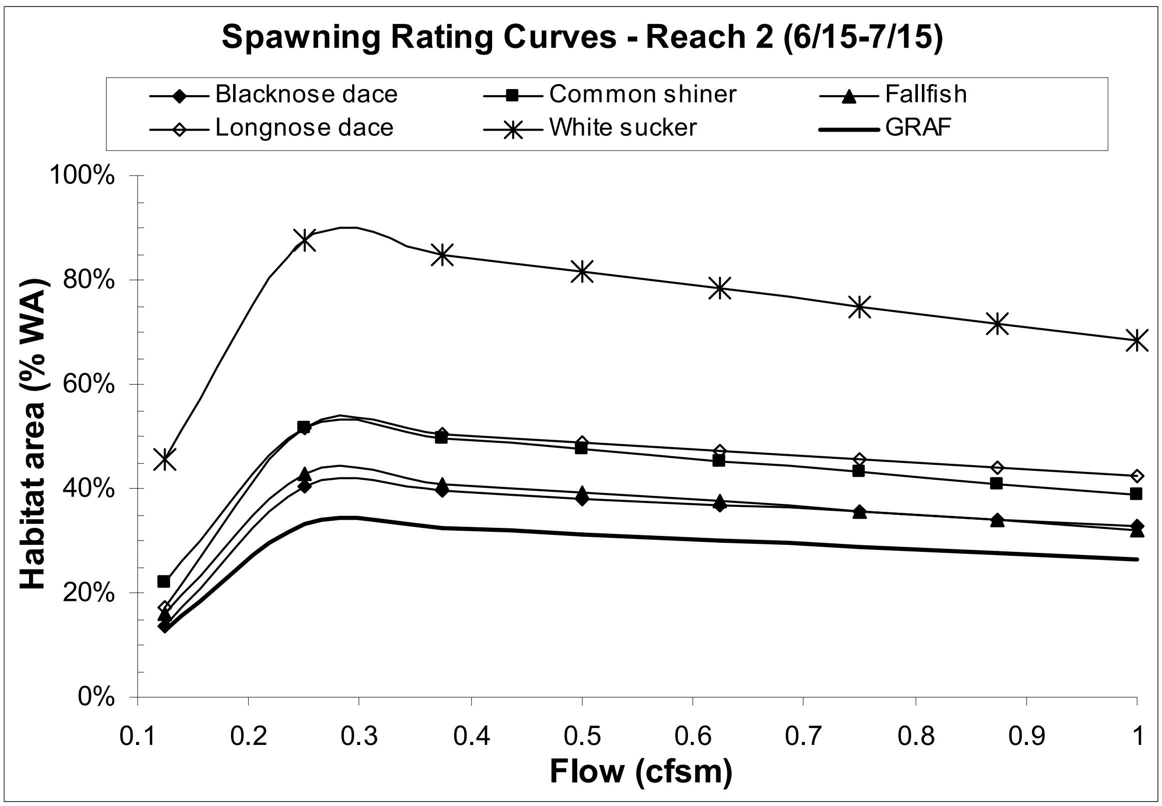


Figure 20. Habitat Rating curves for Reach 2 species during the Spawning bio-period.

Anadromous Spawning

Atlantic salmon habitat increased sharply from 20% available habitat at 0.1 cfsm to nearly 55% available at 0.3 cfsm, and then continued to increase gradually with increasing flows. American shad habitat area decreased slightly with increasing flow from 0.1 to 0.4 cfsm, at which point they each gained habitat area. American shad gained the most habitat area, increasing from 8% at 0.4 cfsm to 35% at 1.0 cfsm (Figure 21).

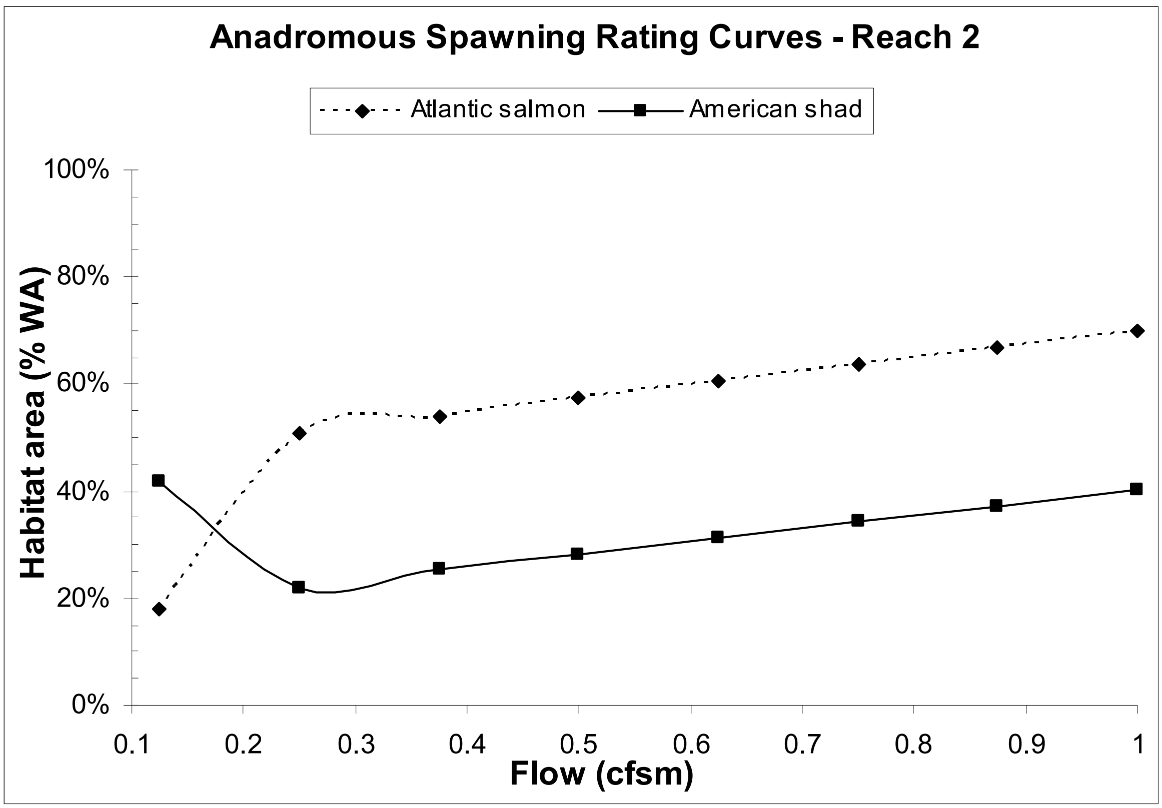


Figure 21. Habitat Rating curves for Atlantic salmon and American shad spawning bio-period in Reach 2.

Reach 3

Rearing and Growth Bio-period

Atlantic salmon, brook trout, odonates, and YOY each had increasing available habitat area with increasing flow. However, there was very little available habitat for odonates. American eel had the greatest available habitat, starting with 96% at flows of 0.1 cfsm, increasing to 100% at 0.3 cfsm and then decreasing to 92% at 1.0 cfsm. Slimy sculpin's habitat area decreased sharply from 26% at 0.1 cfsm to 10% at 0.25 cfsm and then rose gradually with increasing flow to 32% at 1.0cfsm. GRAF did not appear to be flow sensitive at this reach (Figure 22).

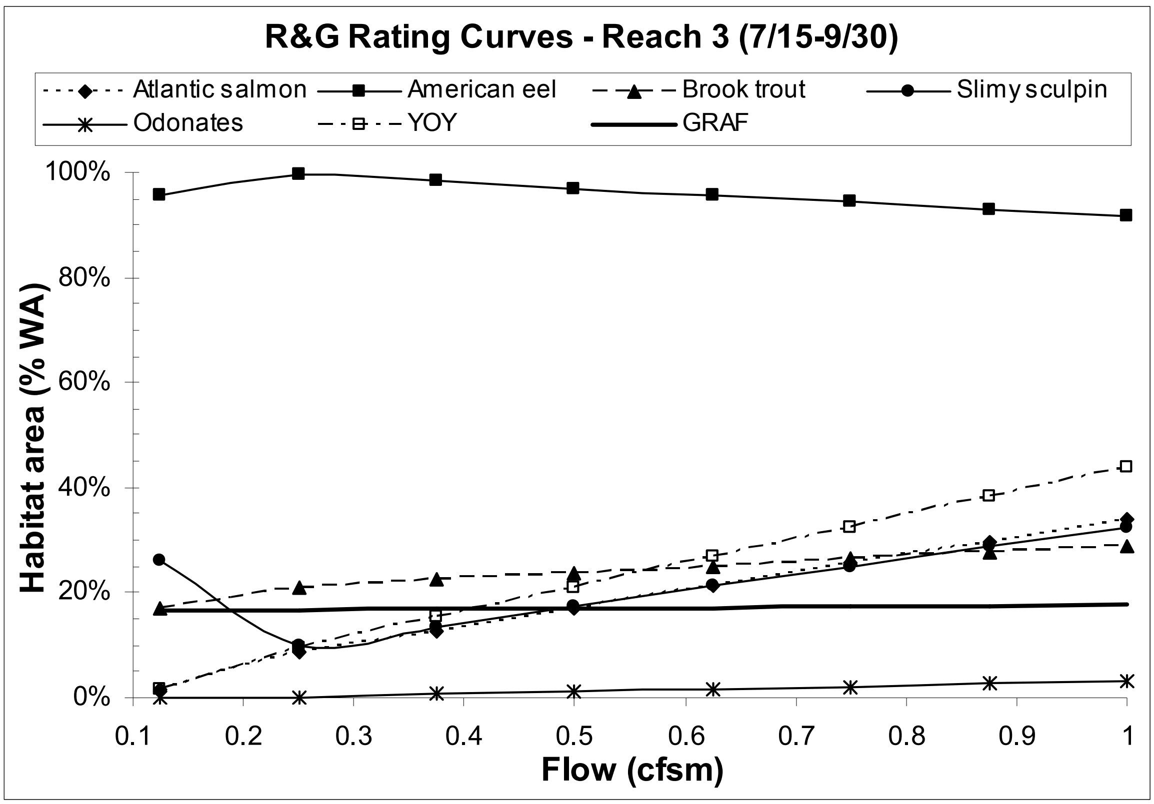


Figure 22. Habitat Rating curves for Reach 3 species during the R&G bio-period.

Spawning

Blacknose dace, common shiner, fallfish, longnose dace, white sucker, and GRAF all had increasing habitat area availability with flow. However, with the exception of white sucker, they all had relatively limited habitat area at all flows. White sucker gained the most habitat area, increasing from 23% at 0.1 cfsm to 35% at 1.0 cfsm (Figure 23).

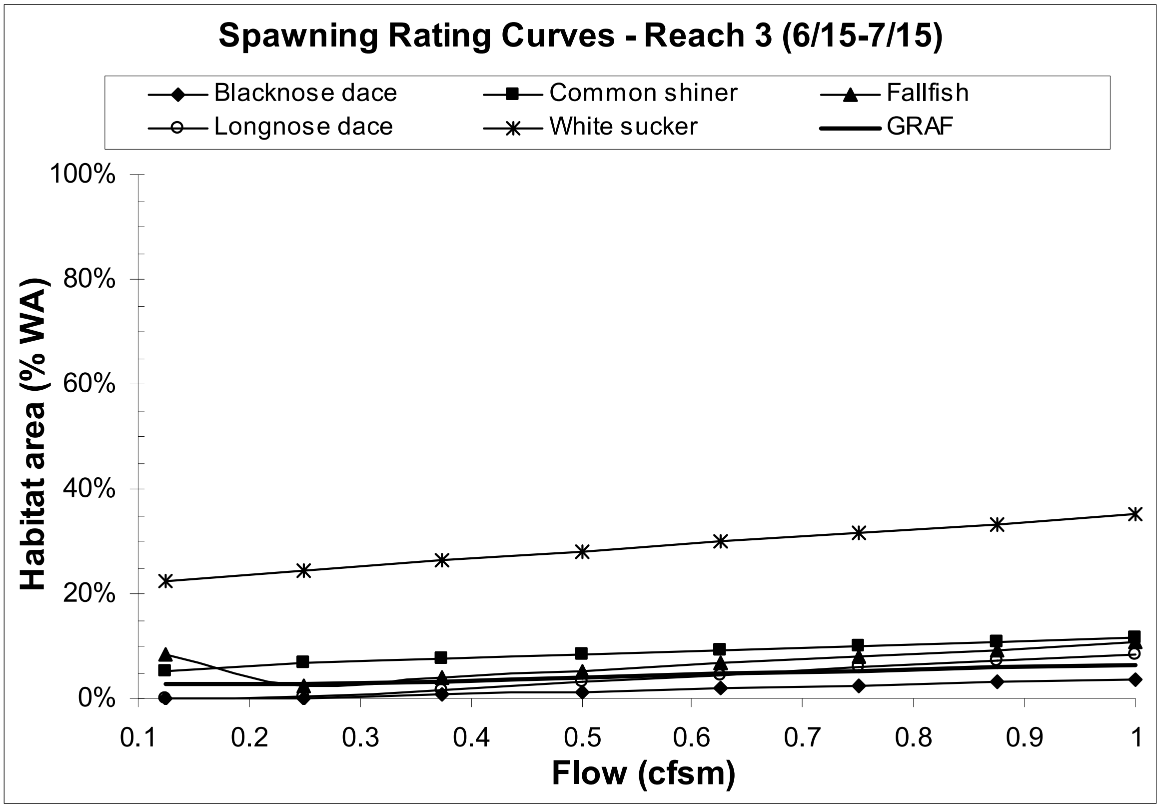


Figure 23. Habitat Rating curves for Reach 3 species during the Spawning bio-period.

Anadromous Spawning

Habitat area for American shad spawning increased from 25% at 0.1 cfsm to 55% at 0.25 cfsm before decreasing steadily to 17% at 1.0 cfsm. There was no available spawning habitat for Atlantic salmon (Figure 24).

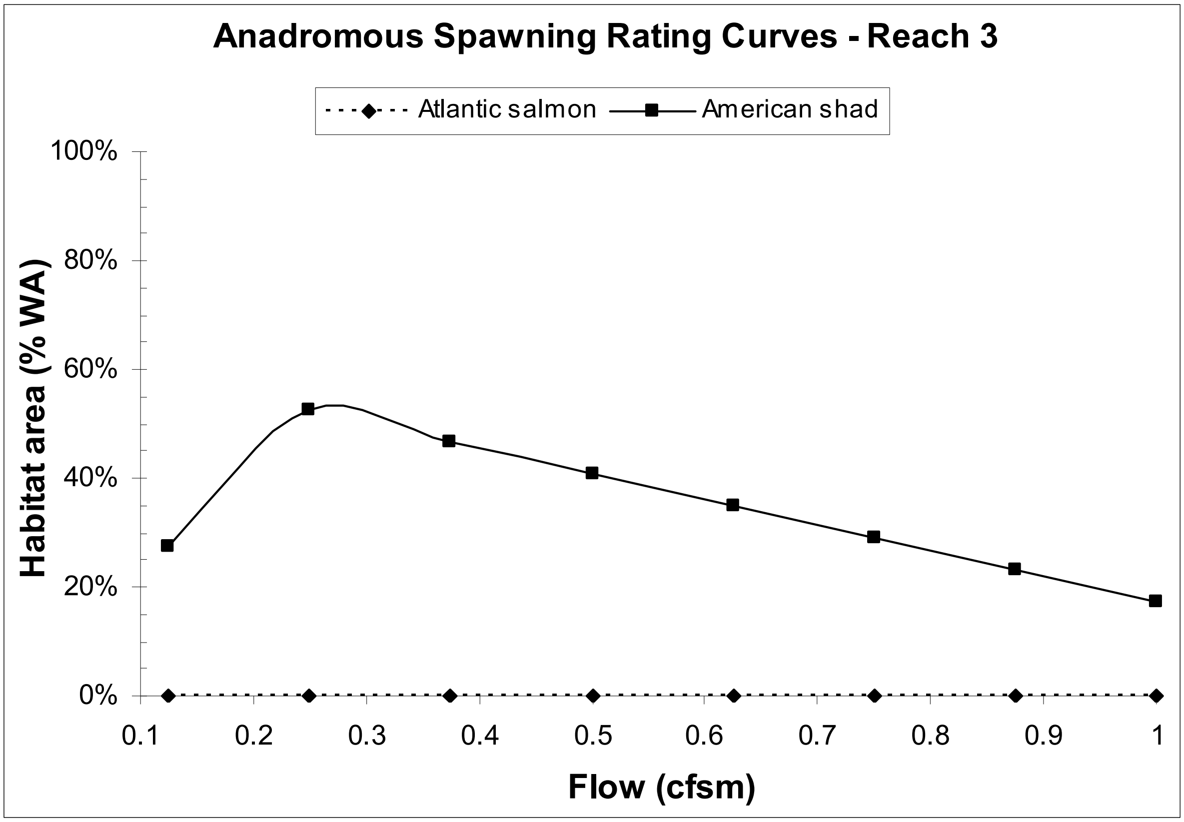


Figure 24. Habitat Rating curves for Atlantic salmon and American shad spawning bio-period in Reach 3.

Reach 4

Rearing and Growth Bio-period

Atlantic salmon, brook trout, odonates, and GRAF each had low percentages of habitat availability and showed very little change with increasing flows. There was very little habitat area for brook trout. American eel and YOY had nearly identical patterns. They both decreased from ~27% habitat area at 0.1 cfsm to ~18% at 0.25 cfsm then increased steadily with additional flow to 46% at 1.0 cfsm (Figure 25).

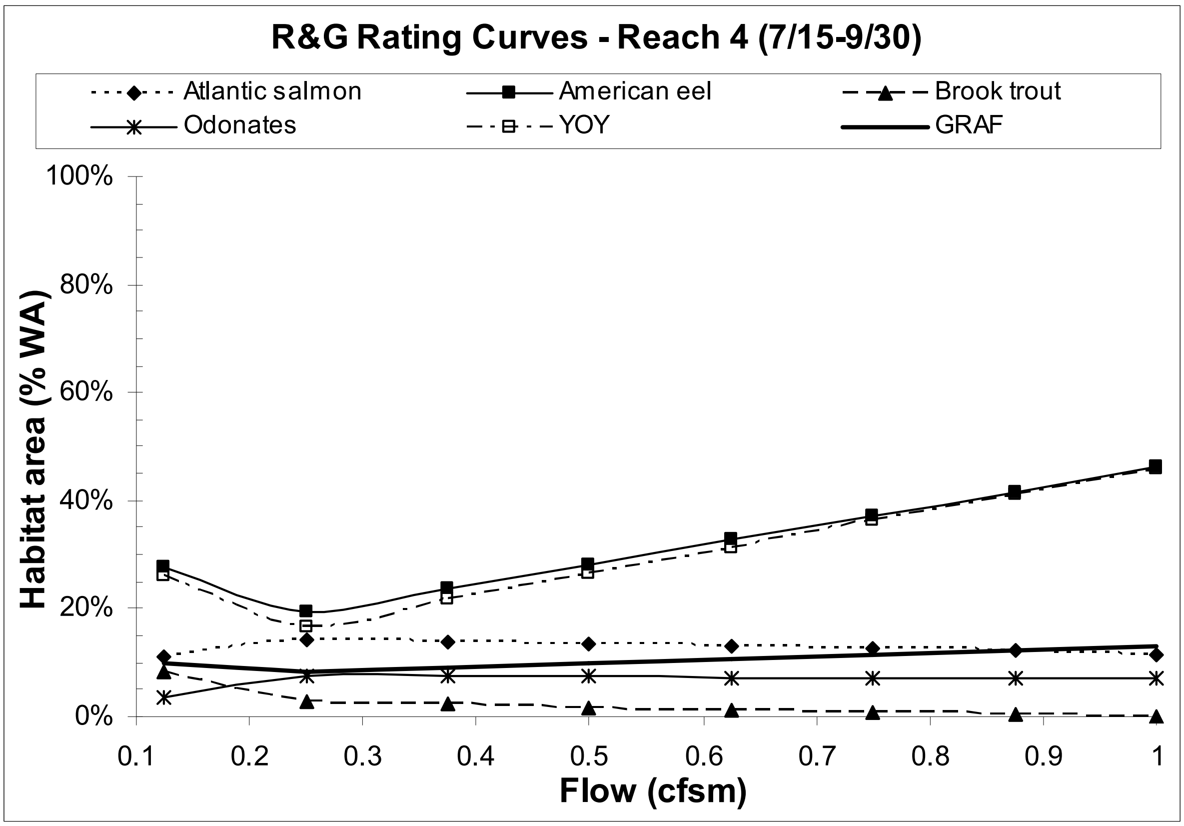


Figure 25. Habitat Rating curves for Reach 4 species during the R&G bio-period.

Spawning

Common shiner, fallfish, and white sucker all had maximum habitat area availability at 0.25 cfsm and decreased slowly with increasing flows. Blacknose dace and GRAF were not flow dependant at this reach. Longnose dace was the only species that had an increase in habitat area with additional flow, increasing from 7% at 0.25 cfsm to 19% at 1.0 cfsm (Figure 26).

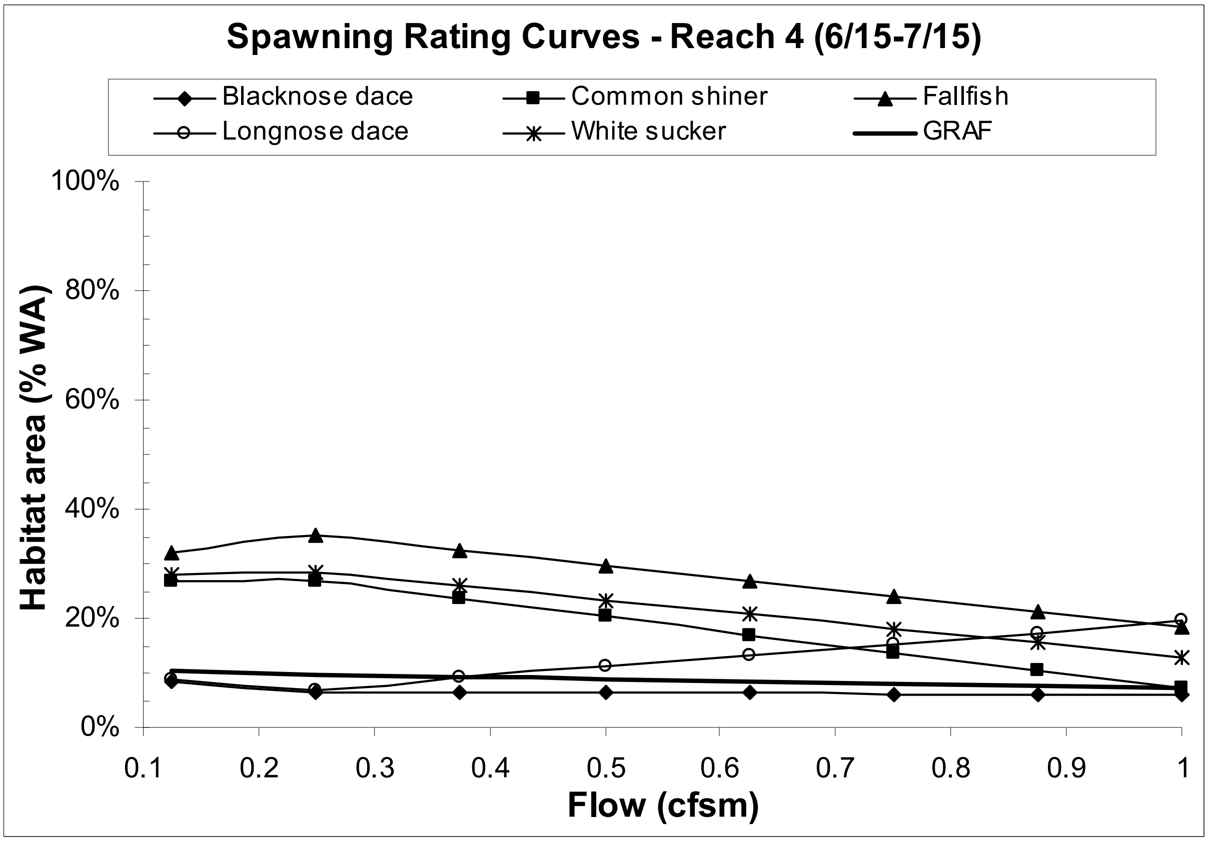


Figure 26. Habitat Rating curves for Reach 4 species during the Spawning bio-period.

Anadromous Spawning

Habitat area for American shad spawning decreased from 74% at 0.1 cfsm to 61% at 0.25 cfsm before increasing steadily to 82% at 1.0 cfsm. Habitat area for Atlantic salmon did not appear to be flow sensitive and ~15% was available at all flows (Figure 27).

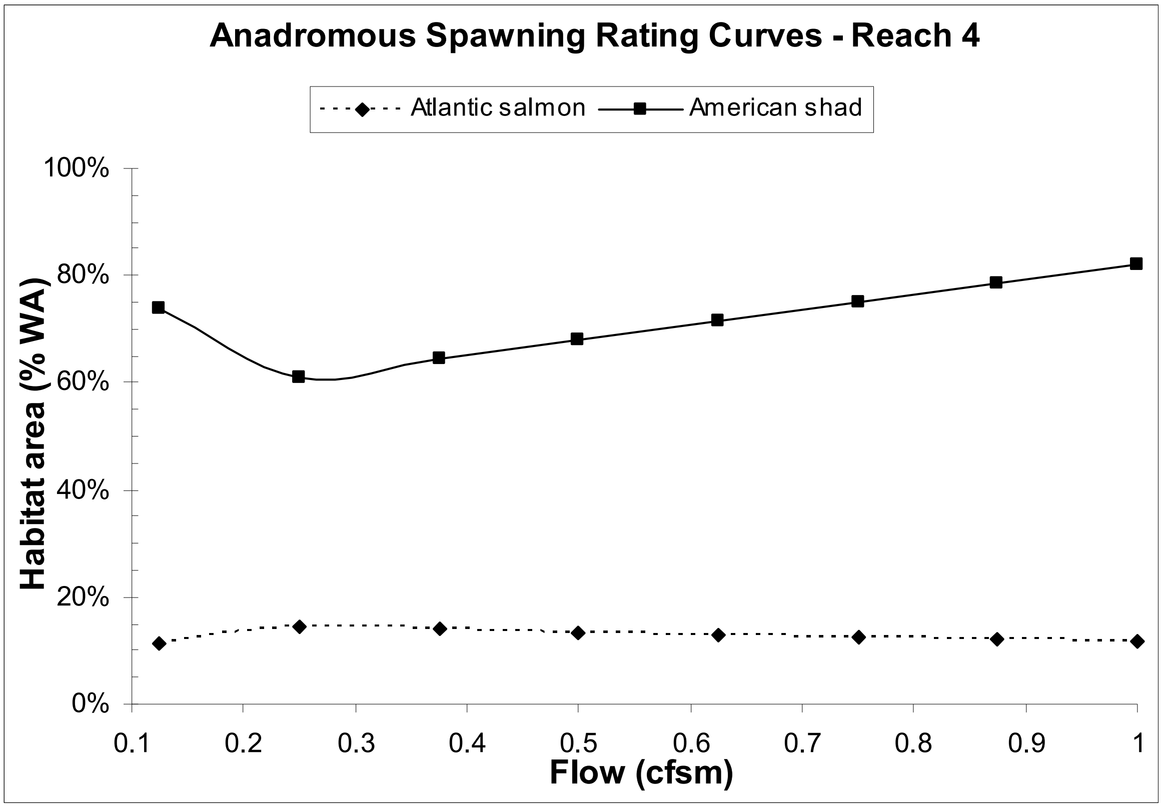


Figure 27. Habitat Rating curves for Atlantic salmon and American shad spawning bio-period in Reach 4.

Reach 5

Rearing and Growth Bio-period

Atlantic salmon, YOY, and GRAF were the only species that showed any increase with additional flow, although nearly stable. American eel, brook trout, and odonates all experienced decreasing habitat areas with increasing flows. American eel had the greatest available habitat, starting with 47% at flows of 0.1 cfsm and decreasing to 26% at 1.0 cfsm (Figure 28).

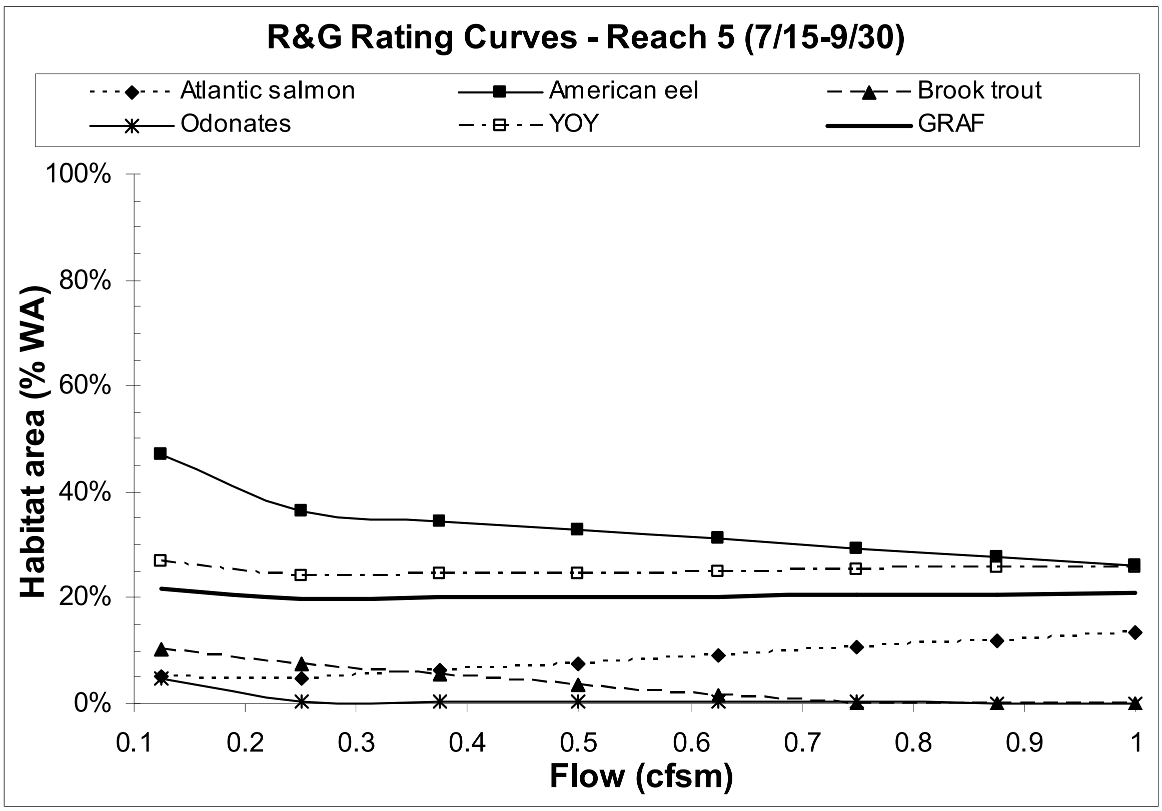


Figure 28. Habitat Rating curves for Reach 5 species during the R&G bio-period.

Spawning

Common shiner, fallfish, white sucker, and GRAF all had decreasing habitat areas with increasing flow. White sucker had greatest available habitat, remaining nearly stable at 35% throughout all flows. Habitat area for Blacknose dace decreased from 12% at 0.25 cfsm to 0% at 0.85 cfsm. Longnose dace was the only species with a slight increase in habitat availability with increasing flow (Figure 29).

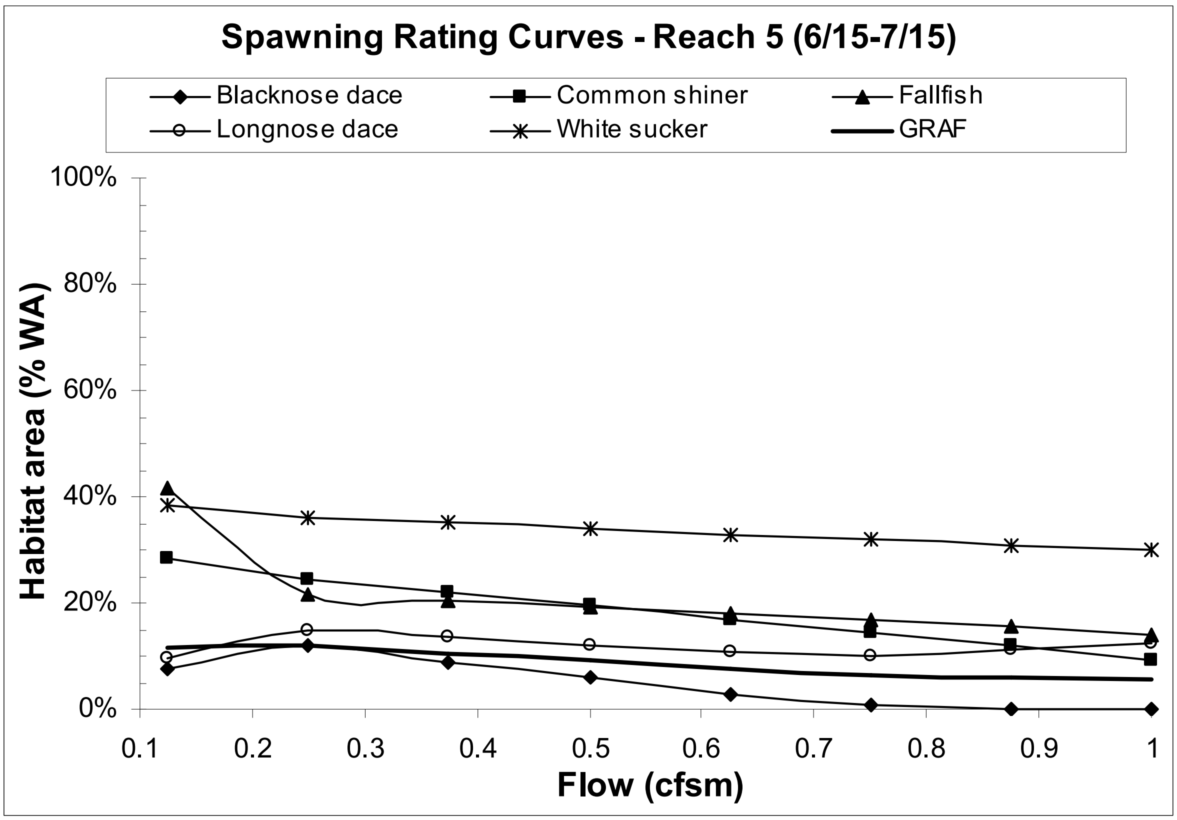


Figure 29. Habitat Rating curves for Reach 5 species during the Spawning bio-period.

Anadromous Spawning

Habitat area for American shad spawning decreased from 35% at 0.1 cfsm to 30% at 0.25 cfsm before increasing steadily to 79% at 1.0 cfsm. Habitat area for Atlantic salmon rose steadily from 5% at 0.1 cfsm to 13% at 1.0 cfsm (Figure 30).

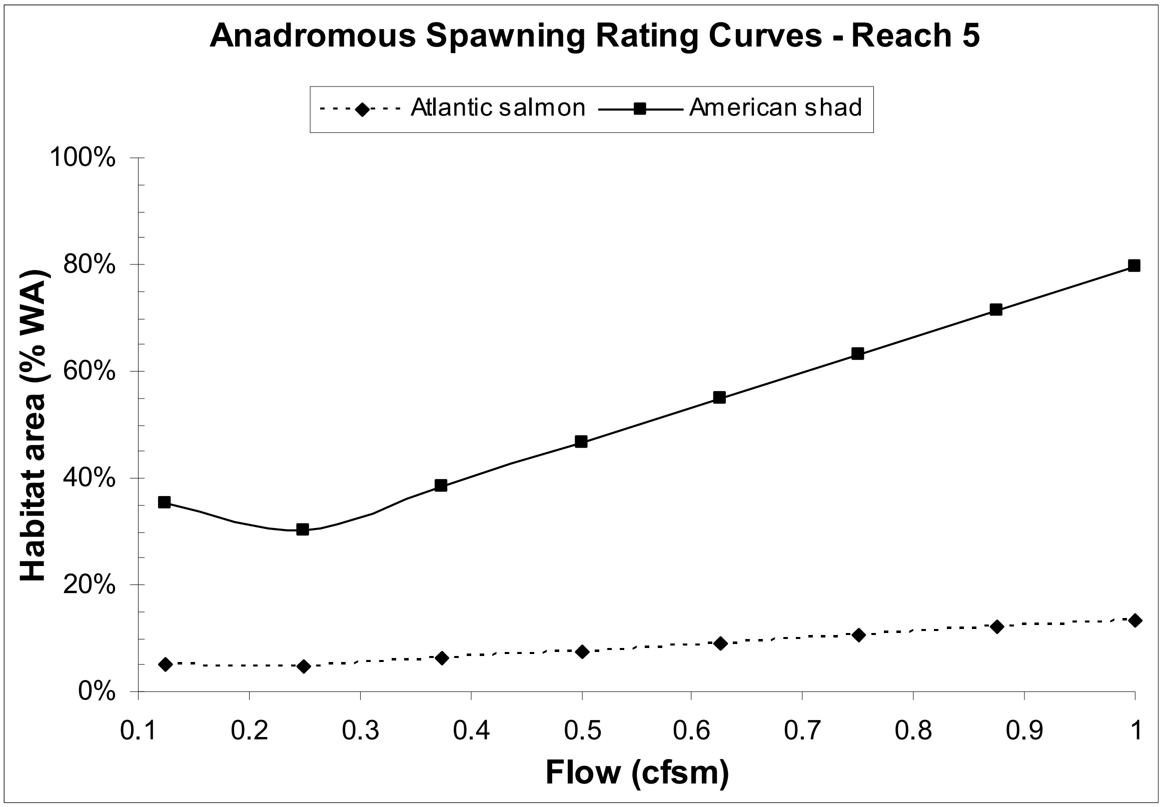


Figure 30. Habitat Rating curves for Atlantic salmon and American shad spawning bio-period in Reach 5.

Reach 6

Rearing and Growth Bio-period

Atlantic salmon, American eel, and brook trout all appeared to have very little habitat (<5%) at this reach, although they also appeared not to be flow dependent. Odonates and GRAF each had slightly decreasing habitat areas with increasing flows. Habitat availability areas for YOY increased slightly from 24% at 0.1 cfsm to 26% at 0.5 cfsm before decreasing rapidly to 0% at 1.0 cfsm. GRAF had the greatest available habitat at all flows, starting with 33% at flows of 0.1 cfsm and decreasing to 20% at 1.0 cfsm (Figure 31).

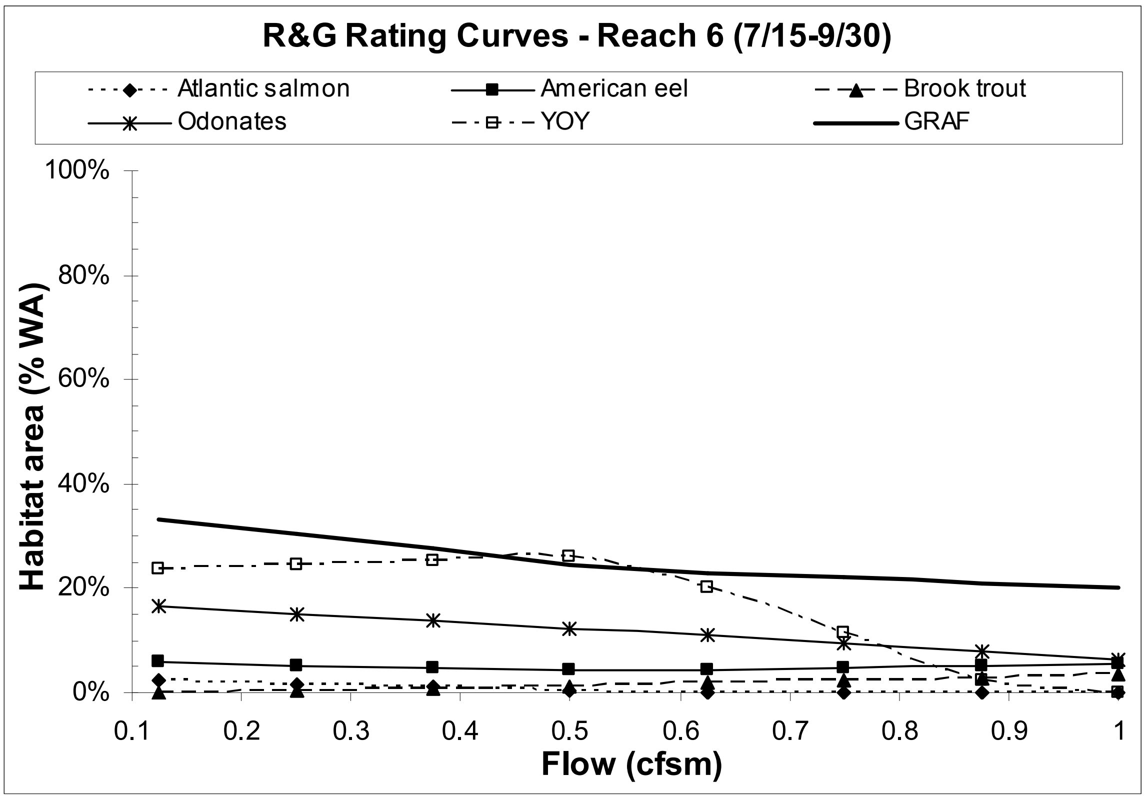


Figure 31. Habitat Rating curves for Reach 6 species during the R&G bio-period.

Spawning

Common shiner, fallfish, white sucker, and GRAF were all non-flow sensitive at this reach, although habitat area availability was low throughout all flows. Common shiner and fallfish had the greatest habitat availability with ~20% at all flows. Blacknose dace and longnose dace each lost habitat with increased flow, trending from 3% at 0.1 cfsm to 0% at 0.85 cfsm and 11% at 0.1 cfsm to 0% at 0.75 cfsm respectively (Figure 32).

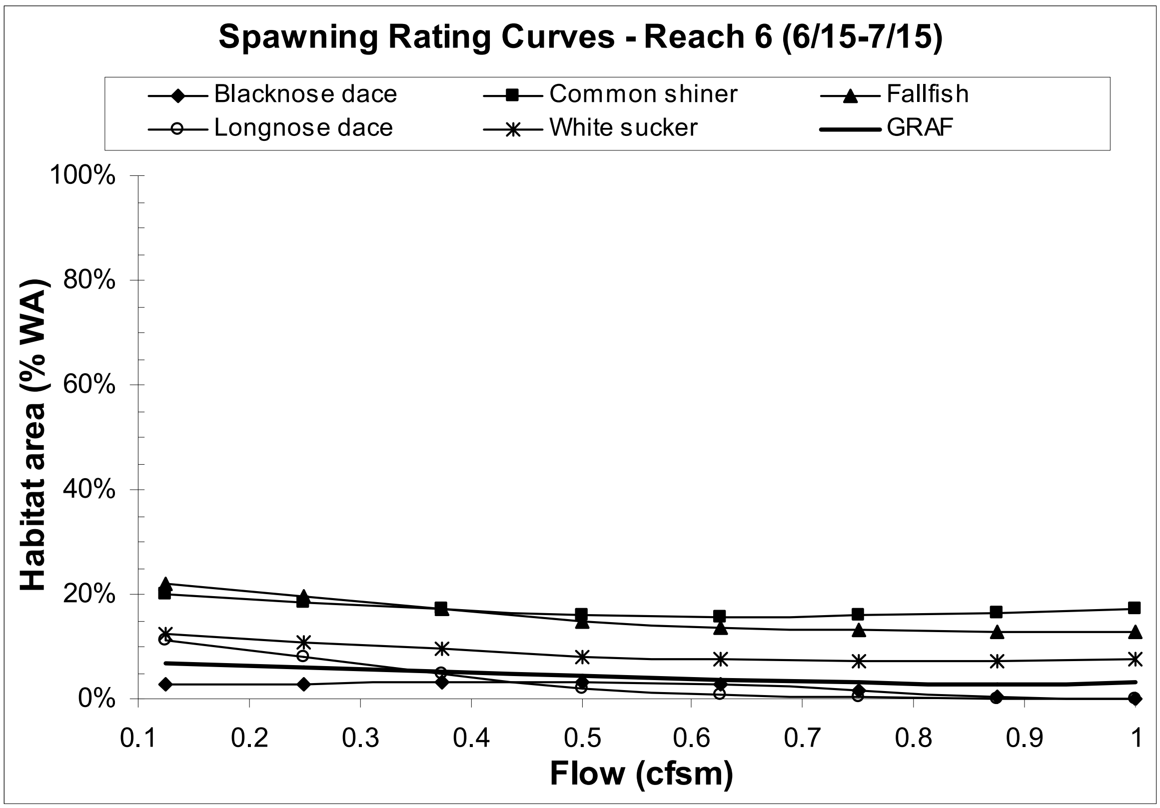


Figure 32. Habitat Rating curves for Reach 6 species during the Spawning bio-period.

Anadromous Spawning

Habitat area for American shad spawning increased from 45% at 0.1 cfsm to 64% at 0.5 cfsm before increasing steadily to 59% at 1.0 cfsm. Habitat area for Atlantic salmon decreased slightly from 3% at 0.1 cfsm to 0% at 0.5 cfsm (Figure 33).

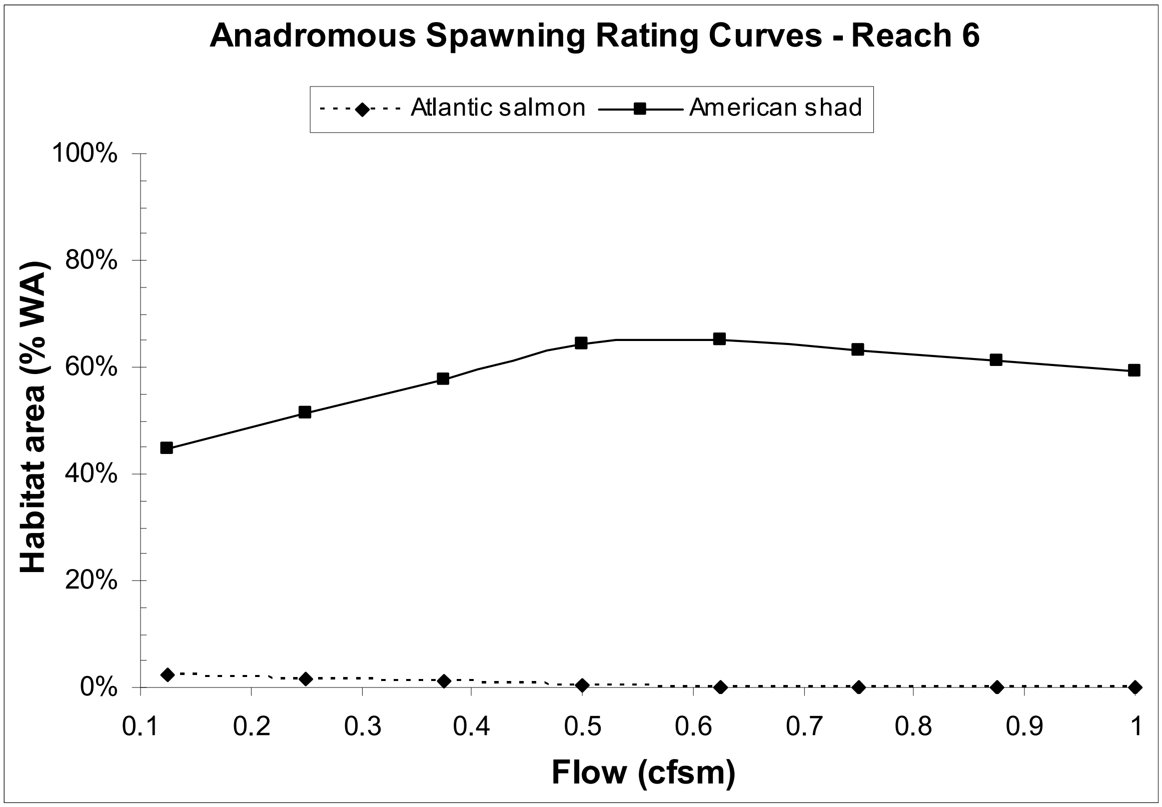


Figure 33. Habitat Rating curves for Atlantic salmon and American shad spawning bio-period in Reach 6.

Reach 7

Rearing and Growth Bio-period

American Eel and brook trout each gained habitat area with increasing flow from ~5% at 0.1 cfsm to ~15% at 1.0 cfsm. There was essentially no Atlantic salmon habitat available in this reach. GRAF species habitat area decreased from 22% at 0.1 cfsm to 14% at 0.5 cfsm and then remained stable with increasing flow. YOY habitat was largely non-flow dependant remaining at around 24%, with the exception of a slight rise in habitat area to 32% at 0.25 cfsm. Habitat area for odonates increased from 40% at 0.1 cfsm to 48% at 0.25 cfsm before decreasing steadily to 13% at 0.6 cfsm and then remaining stable (Figure 34).

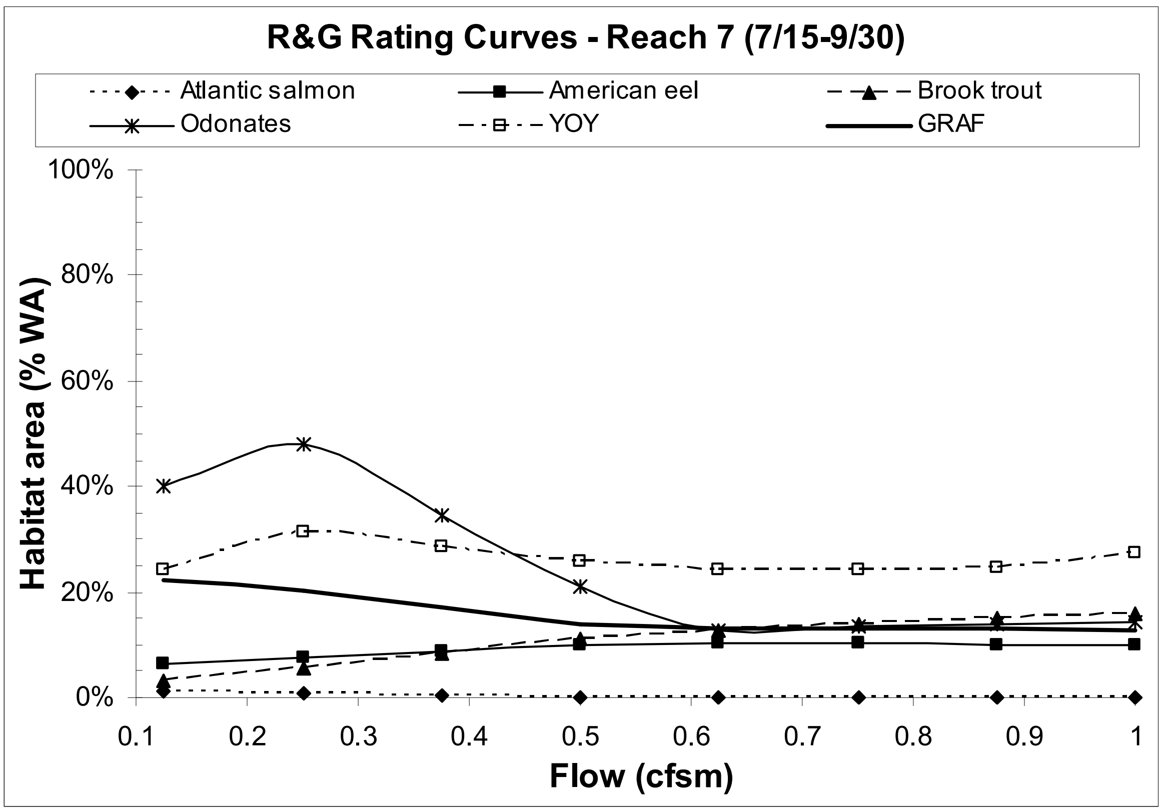


Figure 34. Habitat Rating curves for Reach 7 species during the R&G bio-period.

Spawning

Habitat areas for the species blacknose dace, common shiner, fallfish, longnose dace, white sucker, and GRAF all decreased with increasing flow from 0.1 cfsm to 0.5 cfsm and then remained stable with additional flow. All species had less than 20% suitable spawning area (Figure 35).

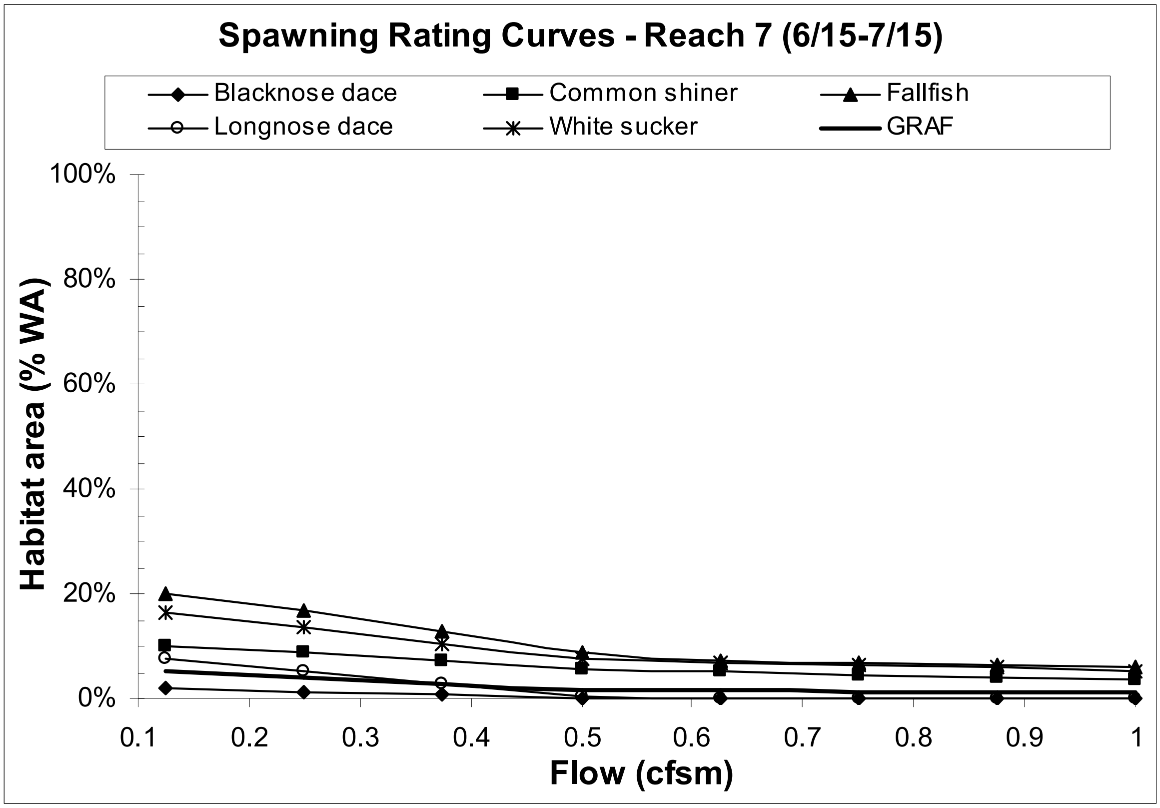


Figure 35. Habitat Rating curves for Reach 7 species during the Spawning bio-period.

Anadromous Spawning

Habitat area for American shad spawning increased from 15% at 0.1 cfsm to 19% at 0.25 cfsm before declining to 7% at 0.6 cfsm and then remaining stable with additional flow. There was no available salmon spawning habitat in this reach (Figure 36).

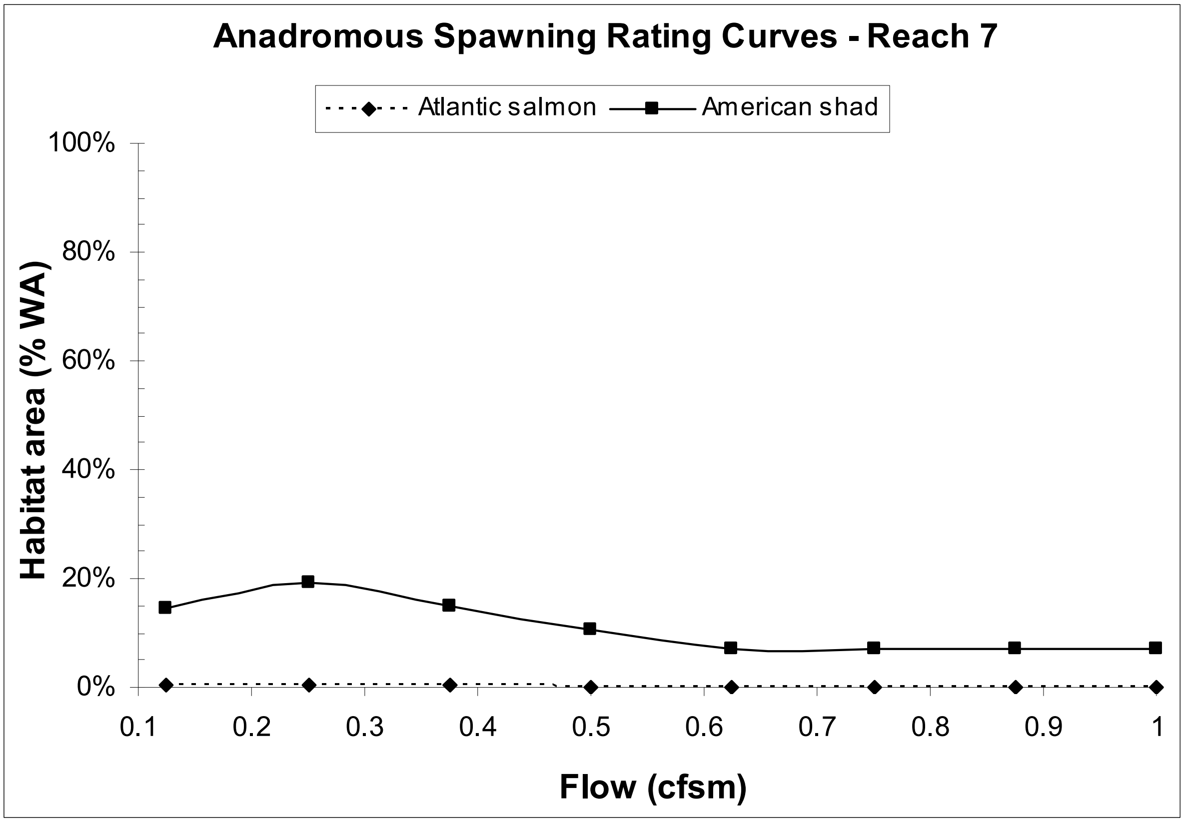


Figure 36. Habitat Rating curves for Atlantic salmon and American shad spawning bio-period in Reach 7.

River Restoration Simulation

Results of assessment methods were integrated into a GIS model that can be used to test management scenarios that would enhance habitat in addition to PISF. Based on known habitat needs of aquatic species geomorphologic setting, and historical information, river channel improvements due to flow or other habitat manipulations (e.g. bank stabilization, or connecting side arms) can be simulated by changing habitat attributes recorded during the field surveys. The potential of these measures can be analyzed by simulation of the gain in fish habitat.

The model modifications investigated a minimally invasive and low-cost restoration option for the Souhegan River. After completing the mapping surveys, it was clear that there was an absence of woody debris in the river. Simulation efforts were therefore geared toward restoration of river canopy cover and the implied addition of woody debris in the attributes tables. It is acknowledged that the addition of woody debris could have an effect on the distribution and size of hydromorphologic units and other intrinsic attributes, but the prediction of these changes is limited. The model rating curves are therefore a look at the instantaneous available habitat changes. Since these factors would affect only the Rearing and Growth habitat model, the analysis was conducted for this season only. A site-by-site listing of all attribute and HMU modifications follows below.

Site 1:

- Woody debris maximized in all HMUs.
- Canopy cover set to present if not already there.
- Information from site 1 used to simulate removal of the Greenville, NH impoundment.

Site 2

- Woody debris increased by a category. If previously absent, then set to present and if previously present, then set to abundant.
- Undercut bank presence added to cut banks in upper sections.
- Canopy cover increased in upper section where site is exposed by road cut.

Site 3

- This site was removed from the restoration simulation model because of possible river modifications related to the large highway overpass.
- Information from site 4 (~500 m downstream) used to represent this area.

Site 4

- Woody debris increased by a category. If previously absent, then set to present and if previously present, then set to abundant.

Site 5

- Woody debris increased by a category. If previously absent, then set to present and if previously present, then set to abundant.
- Canopy cover set to present if not already there.
- Information from site 5 used to simulate the removal of the two Wilton, NH impoundments.

Site 6

- Woody debris increased by a category. If previously absent, then set to present and if previously present, then set to abundant.
- Canopy cover set to present if not already there.
- Backwaters (HMU# 60216, 60526, 60128) modified and reconnected to form a sidearm.
- Backwaters (HMU# 60525, 60125, 60516) enlarged.
- Backwater (HMU# 61019) modified and reconnected to form a sidearm.

Site 7

- Woody debris set to present if not already there.
- A backwater (HMU# 70525) created in a former oxbow using data from HMU# 70510.
- A sidearm (HMU# 70526) created in a floodplain scar using data from HMU#70514.
- A backwater (HMU# 71036) created in a former oxbow using data from HMU# 71017.
- A sidearm (HMU# 71037) created in a floodplain scar using data from HMU#71023.
- Information from site 7 used to simulate the removal of the two Milford, NH impoundments.

Site 8

- Woody debris set to present if not already there.
- Canopy cover increased by a category. If previously absent, then set to present and if previously present, then set to abundant.

Site 9

- Woody debris set to abundant.
- Canopy cover set to present if not already there.

Site 10

- Woody debris increased by a category. If previously absent, then set to present and if previously present, then set to abundant.
- Canopy cover increased by a category. If previously absent, then set to present and if previously present, then set to abundant.

Site 11

- Removed from the simulation, which ended at the USGS gauging site just above Wildcat Falls (see below).

River Simulation Results

The following are descriptions of observed changes in suitable habitat areas between the original MesoHABSIM model and the simulation of river restoration improvements.

Reach 1

Available habitat area for American eel, brook trout, YOY, and GRAF increased at all flows with the addition of woody debris and canopy shading. Atlantic salmon habitat remained nearly identical to pre-modified conditions. Slimy sculpin gained habitat at low flows, but experienced a net loss at high flows. Overall slimy sculpin's available habitat remained more stable with at least 25% at all flows. There was still no available habitat for odonates in the restoration model. Modification had the greatest positive impact on brook trout, YOY, and GRAF in this reach (Figure 37).

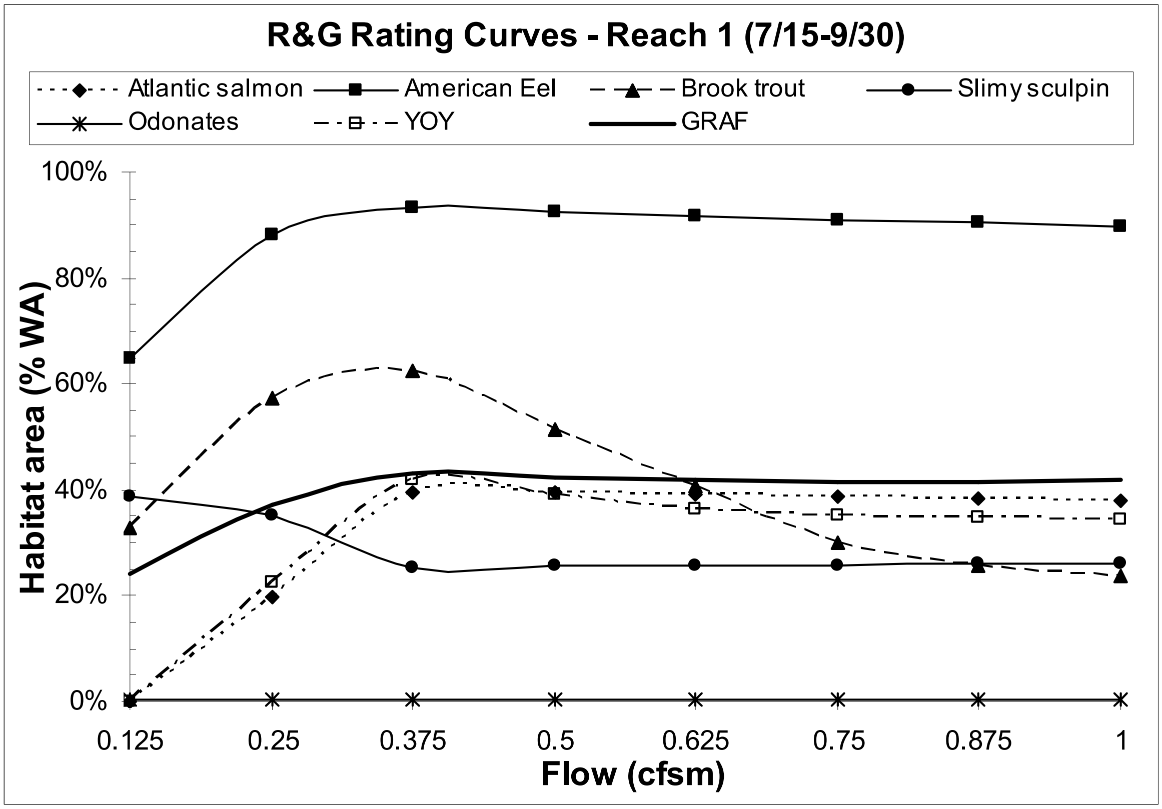


Figure 37. Habitat Rating curves for Reach 1 river restoration simulation species during the R&G bio-period.

Reach 2

Available habitat area for American eel, odonates, slimy sculpin, GRAF, and Atlantic salmon did not change significantly between the two models. Habitat availability for brook trout increased at all flows, particularly between 0.2 and 0.6 cfsm. Modification had the greatest positive impact on YOY habitat area in this reach, remaining above 60% in flows above 0.2 cfsm (Figure 38).

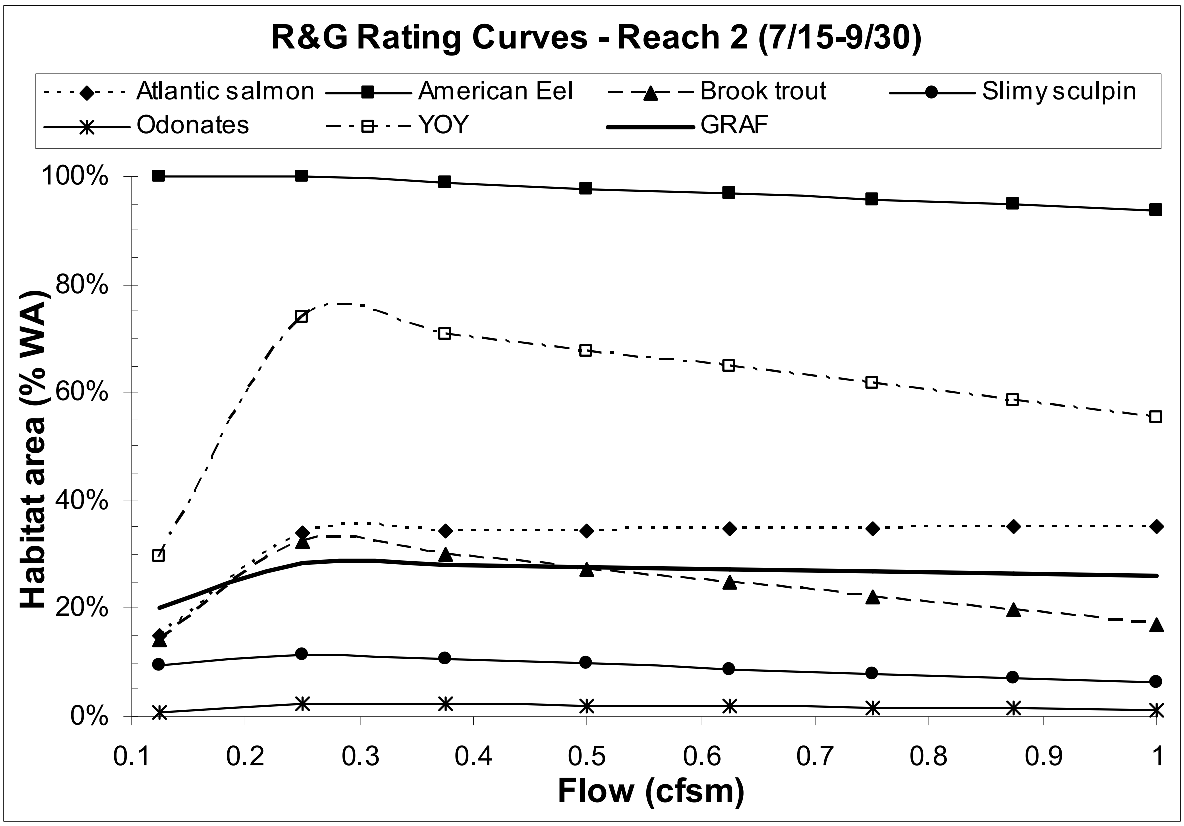


Figure 38. Habitat Rating curves for Reach 2 river restoration simulation species during the R&G bio-period.

Reach 3

Available habitat area for Atlantic salmon, American eel, odonates, and GRAF did not change significantly between the two models. Habitat availability for brook trout increased dramatically, surpassing 55% in all flows. YOY habitat area increased slightly in a linear fashion from 0% at 0.1 cfsm to 57% at 1.0 cfsm. Modification had the greatest positive impact on brook trout and slimy sculpin in this reach (Figure 39).

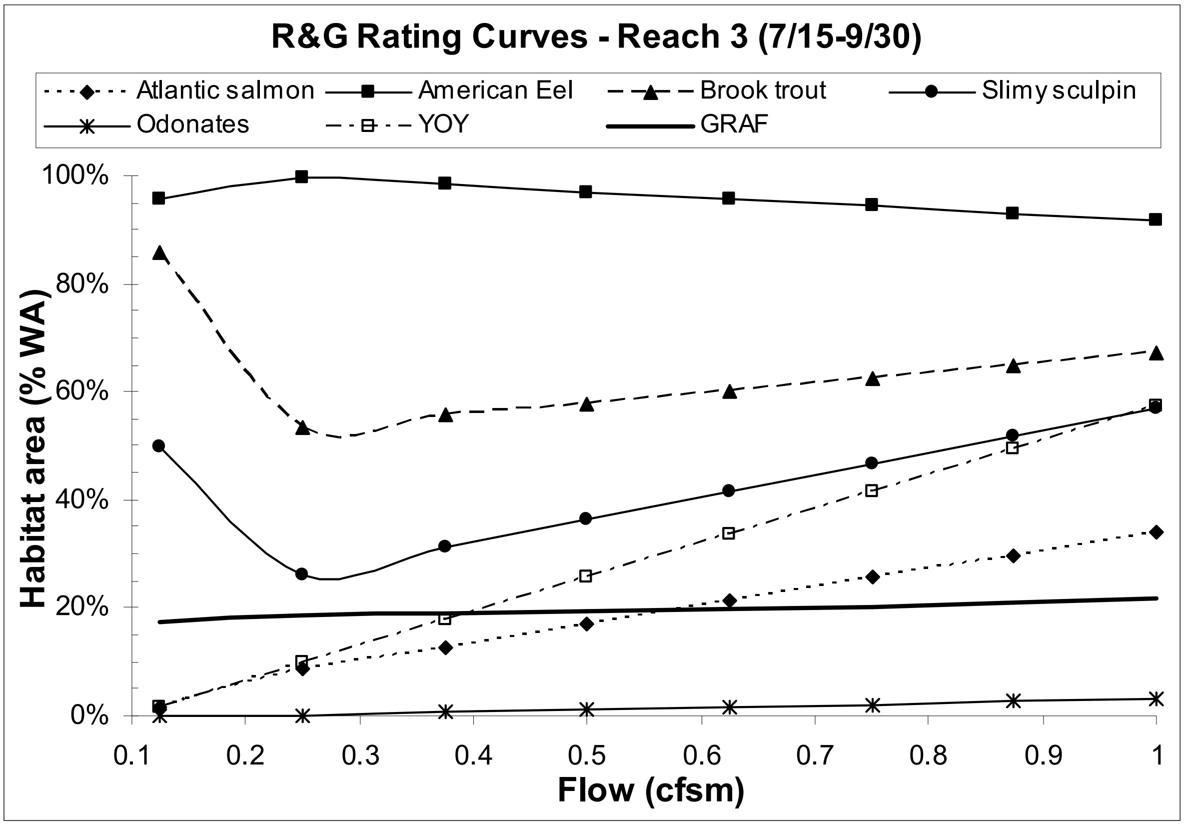


Figure 39. Habitat Rating curves for Reach 3 river restoration simulation species during the R&G bio-period.

Reach 4

YOY and GRAF habitat area increased significantly in our restoration simulation model at all flow conditions, generally remaining above 50%. Odonate habitat area, in the restoration model, had significant gains with flows in excess of 0.25 cfsm. Available habitat area for Atlantic salmon and American eel did not change significantly between the two models. Brook trout gained some habitat area at higher flows, but generally remained at low levels. Modification had the greatest positive impact on YOY, GRAF, and odonates in this reach (Figure 40).

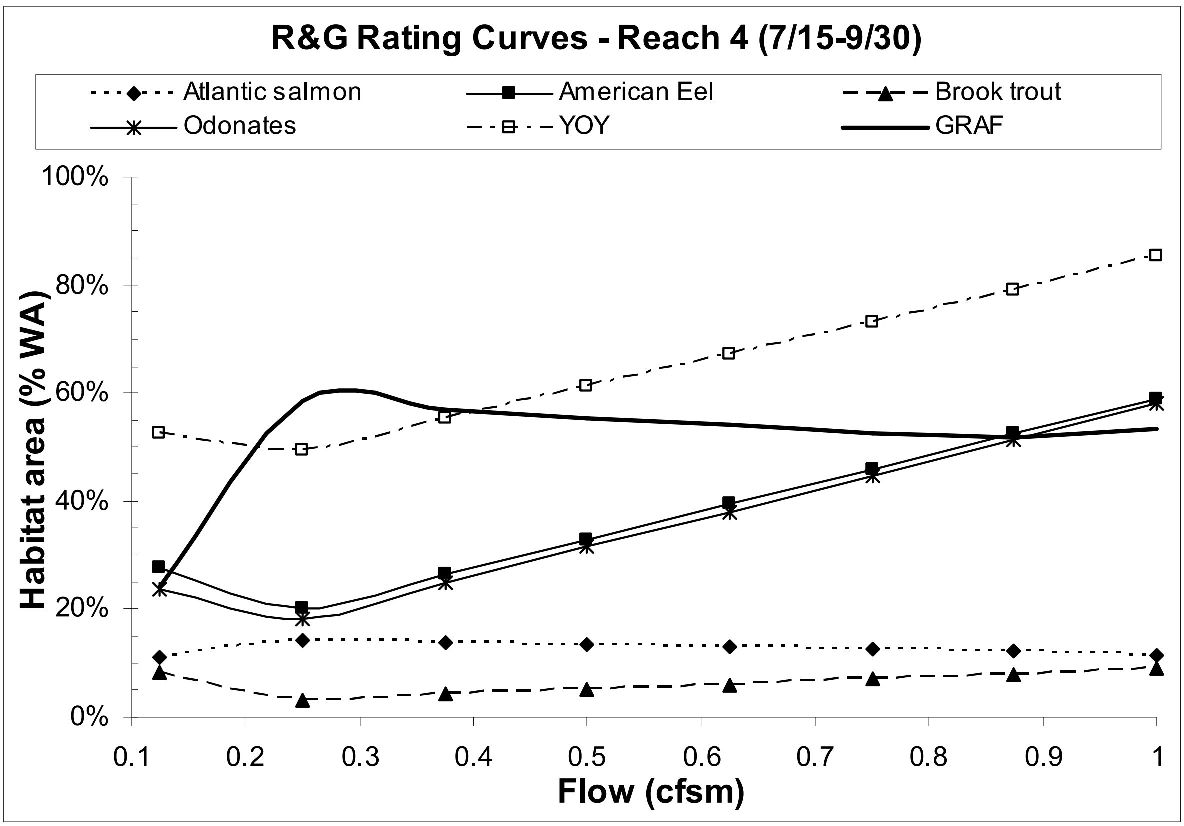


Figure 40. Habitat Rating curves for Reach 4 river restoration simulation species during the R&G bio-period.

Reach 5

YOY habitat area increased significantly in our restoration simulation model at flows above 0.25 cfsm. Available habitat area for Atlantic salmon, American eel, GRAF, and odonates did not change significantly between the two models. Brook trout gained some habitat area at higher flows, but generally remained at low levels. River modification showed little increased habitat in this reach, with the exception of YOY at flows above 0.3 cfsm (Figure 41).

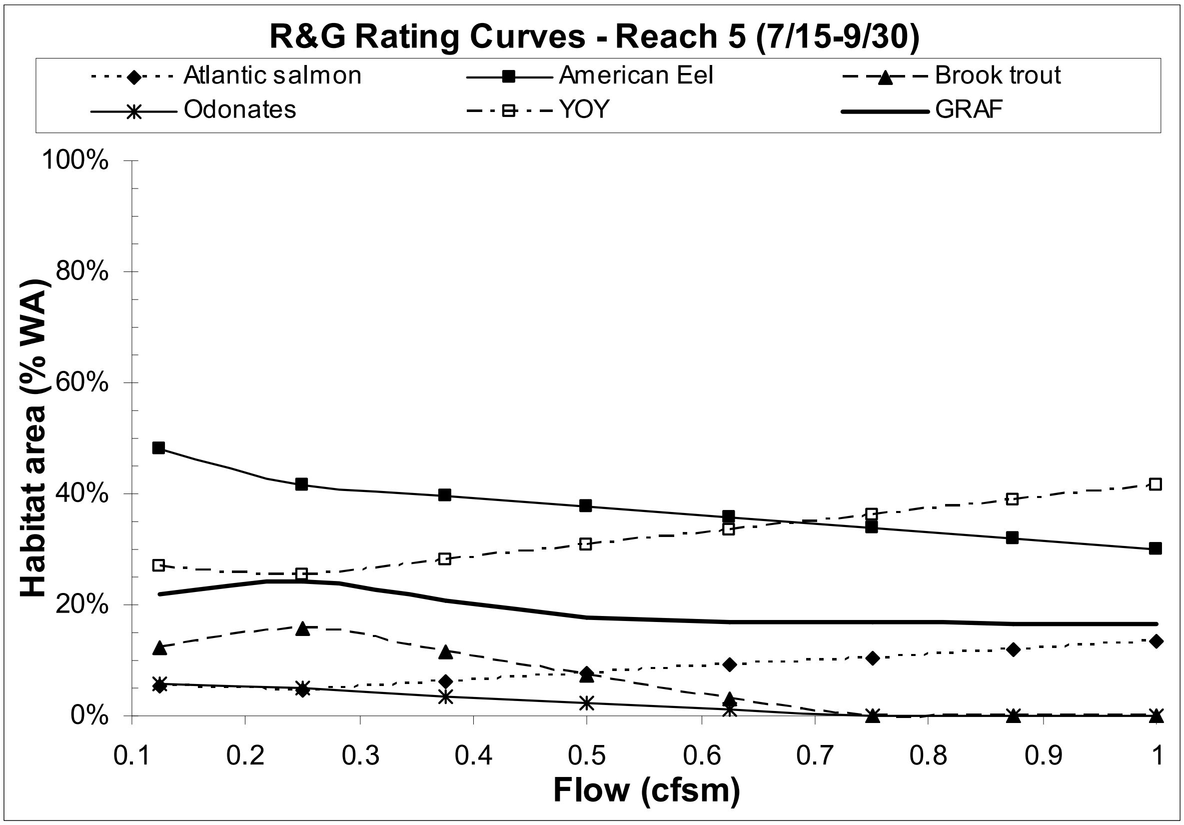


Figure 41. Habitat Rating curves for Reach 5 river restoration simulation species during the R&G bio-period.

Reach 6

Habitat area for American eel, Atlantic salmon, YOY, and GRAF did not change significantly between the two models. Odonate habitat area increased slightly at all flows with the greatest increase at flows over 0.5 cfsm. Brook trout habitat area remained mostly unchanged until at flows greater than 0.5 cfsm where habitat area began to increase. River modification showed little increased habitat in this reach, with the exception of odonates and brook trout at flows above 0.3 cfsm (Figure 42).

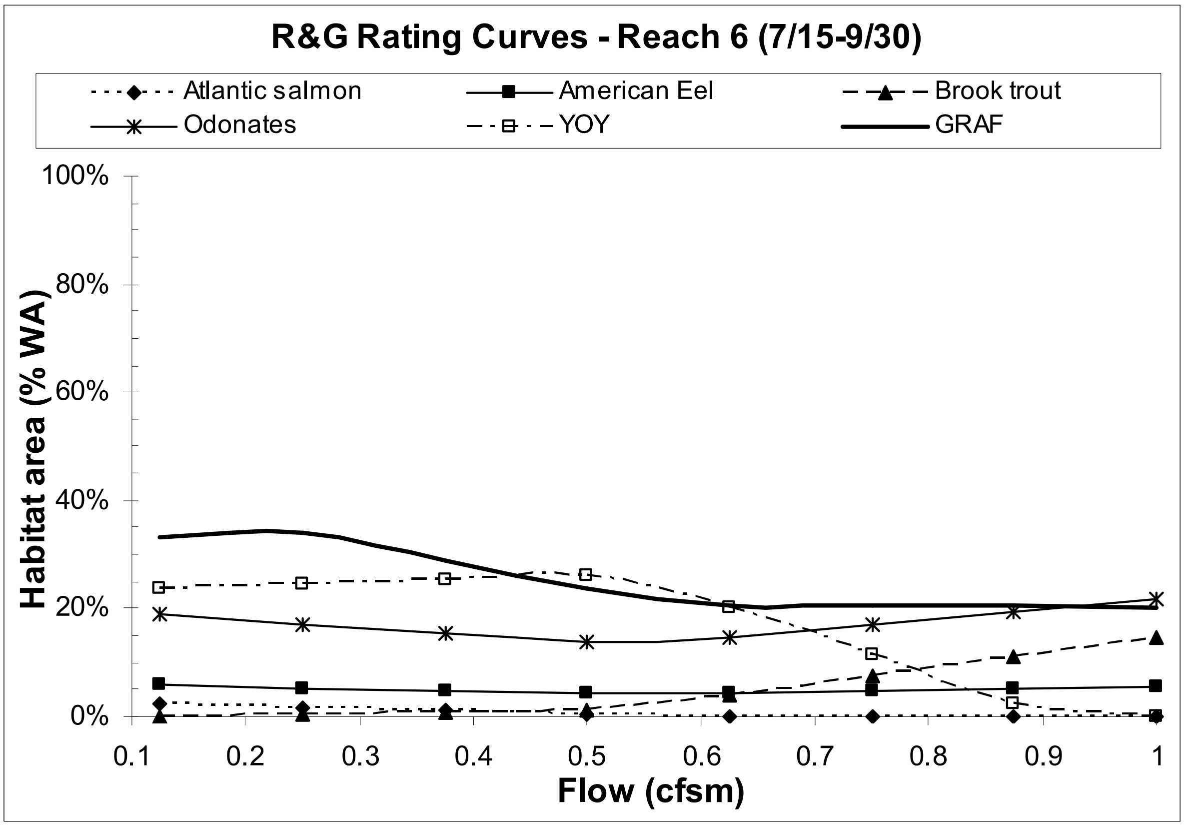


Figure 42. Habitat Rating curves for Reach 6 river restoration simulation species during the R&G bio-period.

Reach 7

Habitat area for Atlantic salmon, American eel, brook trout, and YOY did not change significantly between the two models. There was a slight overall decrease in habitat area for GRAF species at all flows. Habitat area for odonates increased significantly at flows between 0.1 and 0.5 cfsm, but were slightly lower at flows over 0.5 cfsm. River modification showed little increased habitat in this reach, with the exception of odonates at flows between 0.1 and 0.5 cfsm (Figure 43).

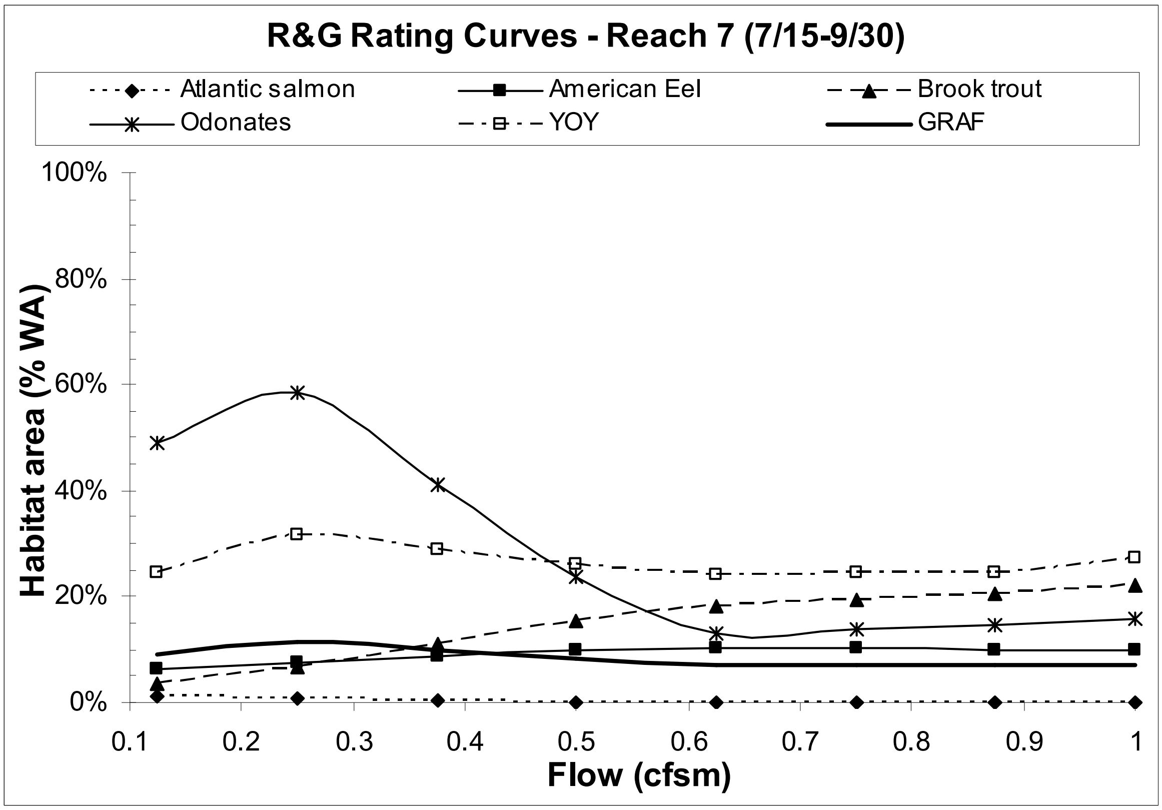


Figure 43. Habitat Rating curves for Reach 7 river restoration simulation species during the R&G bio-period.

Habitat Time Series Analysis

The purpose of this task was to develop habitat augmentation rules to avoid or mitigate both pulse and press disturbances (Niemi et al. 1990). The key criteria for these rules were developed by the determination of habitat stressor thresholds (HST) from their frequency of occurrence. Intra-annual rules should specify the magnitude of extreme habitat that should always be exceeded, as well as the magnitude and the duration of low-habitat events that are common in an average year. Inter-annual rules should define how frequently uncommonly low and long events could occur.

We distinguished two duration types for rare events: persistent lows that can happen two or three years in a row (equivalent to a press disturbance); and catastrophic events that occur on the decadal scale (pulse stressors). All of these rules are organized by annual bio-periods.

To identify HST, habitat time series were developed and the habitat duration curves analyzed, then uniform continuous under-threshold habitat-duration curves (UCUT-curves) modified from Capra et al. (1995) (see Appendix 12). The curves evaluate durations and frequency of continuous events with habitat lower than a specified threshold. With the help of this technique, three habitat quantities that correspond with different types of thresholds in the bio-periods were identified. From inflection points on duration curves and position of UCUTs *rare, critical, and typical* habitat levels were designated.

For each of the thresholds, the longest typical or allowable durations were identified, which demarcated the beginning of persistent low habitat. The shortest of uniquely long durations appearing on the decadal scale are defined as catastrophic durations and are accompanied by their frequency of occurrence.

To develop habitat time series, the habitat rating curves described in the last paragraph are applied to simulated flow time series as developed for specific reaches. Table 15 documents which gages were used to represent flow in a reach and Figure 6 shows their locations. Due to the limited number of flow observation at some gages (caused by floods that damaged most of the gages), the flow readings of neighboring gages were lumped in pairs to provide more robust representation of flows in a reach. Because not all species or life stages are sensitive to flow changes in the habitat use, only rating curves that indicate such habitat are selected for development of habitat time series. During the R&G and resident-species spawning seasons the preference was to choose GRAF as indicator. Only if the GRAF rating curve did not display any changes with flow or if other species were much more flow dependent were rating curves for individual species or the YOY life stage used. During the R&G bio-period the Habitat Duration Curve (HDC) and UCUT curves were computed for selected indicator species in every reach using a time series from neighboring flow gauges.

Because the spawning models were less precise than those for the R&G season and during spawning bio-periods flows are usually higher than in summer, to establish PISF criteria for these times the HDC and UCUTs were computed for the most flow-sensitive reach in a segment. For seasons or reaches where habitat information was insufficient flow based time series analysis were applied.

PISF recommendations were developed for each segment by taking the highest of the habitat needs and the longest allowable and catastrophic durations identified in investigated reaches. For each habitat level flows at the bottom of each Segment necessary to achieve this level were computed. To represent the Upper Souhegan, the location equivalent to gage in Section 25 with a drainage area of 102.3 mi^2 was selected, and for the Lower Souhegan the location of the USGS gage in Merrimack, NH with a drainage area of 171 mi^2 was selected.

R&G Bio-Period

Table 15. Species and life stages selected as habitat indicators in each specific reach. See Appendix 12 for the curves and the PISF criteria established for each reach from the analysis of HDC and UCUTs.

Indicator	GRAF	GRAF	YOY	GRAF	ATS	GRAF	GRAF	**Recommended flows**	
Gauge (SR#)	6-12	16-18	25	31-34	31-34	50-56	50-56	25	USGS
Watershed area (mi^2)	33.9	64.6	102.3	139	139	159	159	102.3	171
Location	**Reach 1**	**Reach 2**	**Reach 3**	**Reach 4**	**Reach 5**	**Reach 6**	**Reach 7**	**Upper**	**Lower**
Common habitat (% WA)	**19**	**30**	**11**	**33**	**6**	**35**	**22.5**		
Allowable duration under (days)	30	25	30	30	30	20	20	30	20
Catastrophic duration (days)	42	45	48	45	45	45	40	42	40
Corresponding flow present (cfsm)	0.4	0.23	0.28	0.6	0.34	0.33	0.33	0.4	0.6
Habitat when restored (% WA)	43	27	15	66	7	30	30		
Critical habitat (% WA)	**10**	**15**	**1.5**	**22.5**	**5.2**	**27**	**15**		
Allowable duration under (days)	15	15	17	10	17	15	15	15	15
Catastrophic duration (days)	35	40	40	15	20	27	27	35	20
Corresponding flow present (cfsm)	0.16	0.04	0.13	0.11	0.15	0.1	0.08	0.16	0.15
Habitat when restored (% WA)	28	19	1	45	5	27	22.5		
Rare habitat (% WA)	**7**	**14**	**1**	**20**	**5**	**22**	**10**		
Allowable duration under (days)	5	5	10	5	5	7	5	5	5
Catastrophic duration (days)	32	10	35	10	10	15	10	30	10
Corresponding flow (cfsm)	0.10	0.02	0.10	0.10	0.11	0.08	0.06	0.1	0.1
Habitat when restored (% WA)	22	14	1.5	40	5	22	15		
Common flow (cfs)	14	15	29	83	47	52	52	41	103
Critical flow (cfs)	5	3	13	15	21	16	13	16	26
Rare flow (cfs)	3	1	10	14	15	13	10	10	17

In Reach 1 commonly GRAF habitat stays under 19 %WA for no longer than 30 days, but 42 days are catastrophic duration. At present conditions this habitat level corresponds with flows of 0.4 cfsm (14 cfs). If habitat was improved by restoration the same flows would more than double the GRAF habitat to 43% WA. Critical events begin if habitat is lower than 10% WA close to 15 days. It becomes catastrophically long at 35 days. At present conditions this habitat level corresponds with flows of 0.16 cfsm (5 cfs). If habitat was improved by restoration the same flows would increase the GRAF habitat three fold to 28% WA. The rare events are when GRAF habitat is lower than 7% WA for no longer then 5 days. If it lasts for longer then 5 days, it creates persistent stress and it is recommended that it will not happen more often than once in 3 years. The drought will be catastrophic if it lasts for more than 32 days and it should not happen more often than every 10 years. At present conditions this habitat level corresponds with flows of 0.1 cfsm (3 cfs). If habitat was improved by restoration the same flows would increase the GRAF habitat three fold to 22% of wetted area

In Reach 2 commonly GRAF habitat stays under 20 %WA for no longer than 25 days, but 45 days are catastrophic duration. At present conditions this habitat level corresponds with flows of 0.2 cfsm (13 cfs). If habitat was improved by restoration the same flows would not provide much more habitat (22% WA). Critical events begin if habitat is lower than 15% WA for durations close to 15 days. It becomes catastrophically long at 40 days. At present conditions this habitat level corresponds with flows of 0.04 cfsm (3 cfs). If habitat was improved by restoration the same flows would increase the GRAF habitat only to 19% WA. The rare events are when GRAF habitat is lower than 14% of wetted area for no longer then 5 days. The drought will be catastrophic if it lasts for more than 10 days. At present conditions this habitat level corresponds with flows of 0.02 cfsm (1 cfs). For GRAF no net habitat gain is provided at these flows with restoration.

In Reach 3 YOY habitat was used as an indicator for necessary flows. Commonly YOY habitat stays under 13 %WA for no longer than 30 days, but 48 days are catastrophic duration. At present conditions this habitat level corresponds with flows of 0.28 cfsm (34 cfs). If habitat was improved by restoration the same flows would provide more habitat (15% WA). Critical events begin if habitat is lower than 1.5% WA close to 17 days. It becomes catastrophically long at 40 days. At present conditions this habitat level corresponds with flows of 0.13 cfsm (12 cfs). If habitat was improved by restoration the same flows would stay similar 1% WA. The rare events are when YOY habitat is lower than 1% of wetted area for no longer then 10 days. The drought will be catastrophic if it lasts for more than 35 days. At present conditions this habitat level corresponds with flows of 0.1 cfsm (10 cfs). For GRAF, no net habitat gain is provided at these flows with restoration.

In Reach 4 commonly GRAF habitat stays under 33 %WA for no longer than 30 days, but 45 days are catastrophic duration already. At present conditions this habitat level corresponds with flows of 0.6 cfsm (83 cfs). If habitat was improved by restoration the same flows would double the habitat (66% WA). Critical events begin if habitat is lower than 22.5% WA close to 10 days. It becomes catastrophically long at 17 days. At present conditions this habitat level corresponds with flows of 0.11 cfsm (15 cfs). If habitat was improved by restoration the same flows would increase the GRAF habitat to 45% WA. The rare events are when GRAF habitat is lower than 20% of wetted area for no longer then 5 days. The drought will be catastrophic if it lasts for more than 10 days. At present conditions this habitat level corresponds with flows of 0.1 cfsm (14 cfs). Again substantial habitat gain can be accomplished at these flows with restoration (40% WA).

In Reach 5 flows Atlantic salmon habitat was used as an indicator for necessary flows. Commonly the habitat stays under 6 %WA for no longer than 30 days, but 45 days are catastrophic duration. At present conditions this habitat level corresponds with flows of 0.34 cfsm (47 cfs). If habitat was improved by restoration the same flows would provide some more habitat for salmon (7% WA). Critical events begin if habitat is lower than 5.2% WA close to 17 days. It becomes catastrophically long at 20 days. At present conditions this habitat level corresponds with flows of 0.15 cfsm (21 cfs). If habitat was improved by restoration the same flows would not change habitat availability for this species. The rare events are when salmon habitat is lower than 5% of wetted area for no longer then 5 days. The drought will be catastrophic if it lasts for more than 10 days. At present conditions this habitat level corresponds with flows of 0.11 cfsm (15 cfs). Again no habitat gain can be accomplished at these flows with restoration (5% WA).

In Reach 6 commonly GRAF habitat stays under 35 %WA for no longer than 20 days, 45 days are catastrophic duration. At present conditions this habitat level corresponds with flows of 0.33 cfsm (52 cfs). If habitat was improved by restoration the same flows would not provide more habitat (33% WA). Critical events begin if habitat is lower than 27% WA close to 15 days. It becomes catastrophically long at 27 days. At present conditions this habitat level corresponds with flows of 0.1 cfsm (16 cfs). If habitat was improved by restoration the same flows would not increase the GRAF habitat. The rare events are when GRAF habitat is lower than 22% of wetted area for no longer than 7 days. The drought will be catastrophic if it lasts for more than 15 days. At present conditions this habitat level corresponds with flows of 0.08 cfsm (13 cfs). Again no substantial habitat gain can be accomplished at these flows with restoration Table 7).

In Reach 7 commonly GRAF habitat stays under 22.5 %WA for no longer than 20 days, 40 days are catastrophic duration. At present conditions this habitat level corresponds with flows of 0.33 cfsm (52 cfs). If habitat was improved by restoration the same flows would provide some more habitat (30% WA). Critical events begin if habitat is lower than 15% WA close to 15 days. It becomes catastrophically long at 27 days. At present conditions this habitat level corresponds with flows of 0.08 cfsm (13 cfs). If habitat was improved by restoration the same flows would increase the GRAF habitat to 23 % WA. The rare events are when GRAF habitat is lower than 10% of wetted area for no longer then 5 days. The drought will be catastrophic if it lasts for more than 10 days. At present conditions this habitat level corresponds with flows of 0.06 cfsm (10 cfs). 5% habitat gain can be accomplished at these flows with restoration (Table 16).

Recommendation

For the Upper Souhegan, the flows should not commonly fall under 0.4 cfsm (41 cfs) for longer than 30 days, nor under 0.16 cfsm (16 cfs) for 15 days, nor under 0.1 cfsm (10 cfs) for

5 days. This rule should not be violated more often than once in three years. Catastrophic durations for these levels are 42, 35, and 30 days, respectively.

For the Lower Souhegan, the flows should not commonly fall under 0.6 cfsm (103 cfs) for longer than 20 days, nor under 0.15 cfsm (26 cfs) for 15 days, nor under 0.1 cfsm (17 cfs) for 5 days. This rule should not be violated more often than once in three years. Catastrophic durations for these levels are 40, 20 and 10, days, respectively.

Atlantic Salmon Spawning Bio-period (October 1 through November 15)

For the Upper Souhegan segment, Reach 2 was selected as the most flow sensitive Atlantic salmon spawning habitat. Commonly the habitat does not stay under 52% WA for longer than 25 days, and a duration of 40 days is already catastrophic. This corresponds with flows of 0.4 cfsm (26 cfs). The critical levels begin below 6% WA (0.1 cfsm – 8 cfs) which should not last longer than 10 days. 20 days of habitat under this level is already catastrophic. According to UCUT analysis the rare events are when habitat drops under 1% (0.6 cfsm – 1 cfs). Those may last up to 10 days and are catastrophic with duration over 20 days (Table 16).

Table 16. Recommended flow augmentation criteria for Atlantic salmon spawning bio-period.

Indicator	GRAF	GRAF	**Recommended flows**	
Gauge (SR#)	16-18	31-34	25	USGS
Watershed area (mi^2)	64.6	139	102.3	171
Location	**Reach 2**	**Reach 5**	**Upper**	**Lower**
Common habitat (% WA)	**56**	**14**		
Allowable duration under (days)	25	20	25	20
Catastrophic duration (days)	40	40	40	40
Corresponding flow present (cfsm)	0.4	1.05	0.4	1.1
Critical habitat	**6**	**6**		
Allowable duration under (days)	10	12	10	12
Catastrophic duration (days)	20	40	20	40
Corresponding flow present (cfsm)	0.06	0.4	0.15	0.6
Rare habitat (%WA)	**1**	**5**		
Allowable duration under (days)	10	5	10	5
Catastrophic duration (days)	20	10	20	10
Corresponding flow present (cfsm)	0.01	0.25	0.04	0.4
Common flow (cfs)	26	146	33	184
Critical flow (cfs)	4	56	9	96
Rare flow (cfs)	1	35	2	70

For the Lower Souhegan, Reach 5 was selected as the most flow sensitive Atlantic salmon spawning habitat. Commonly the habitat does not stay under 14% WA for longer than 20 days, and duration of 40 days is already catastrophic. This corresponds with flows of 1.05 cfsm (146 cfs). The critical levels begin below 6% WA (0.4 cfsm – 56 cfs) which should not last longer than 12 days. 40 days of habitat under this level is already catastrophic. According to UCUT analysis the rare events are when habitat drops under 5% (0.25 cfsm – 35 cfs). Those may last up to 5 days and are catastrophic with duration over 10 days (Table 16).

Recommendation

The flow levels computed for the Upper Souhegan during this bio-period using Atlantic salmon spawning habitat needs are lower than those necessary for GRAF species. Because the habitat is used by both Atlantic salmon and GRAF, it is recommended to use the criteria for GRAF species as developed for the R&G bio-period. The GRAF UCUTs remain the same for the time October 1 through November 15.

For the Lower Souhegan it is recommended that flows at the USGS gage remain under 184 cfs, 96 cfs, and 70 for no longer than 20 days, 12 days and 5 days, respectively, no more often than once in 3 years. In catastrophic situations of the decadal scale it may be lower for 40 days, 40 days, and 10 days, respectively.

Overwintering Bio-period (November 15 through February 28)

During this season no habitat data were available and flow recommendations were based on UCUT analysis of simulated flows at the USGS gage in Merrimack (Table 17). It is recommended that flows not be lower than 205 cfs, 51 cfs, and 31 cfs for longer than 35, 15, and 5 days, respectively. Catastrophic durations are 50, 30, and 10 days for these levels.

Table 17. Recommended flow augmentation criteria for overwintering bio-period.

Indicator	Recommended
Gauge	USGS
Watershed area	171
Common habitat (% WA)	
Allowable duration under (days)	35
Catastrophic duration (days)	50
Corresponding flow present (cfsm)	2
Habitat when restored (% WA)	
Critical habitat	
Allowable duration under (days)	15
Catastrophic duration (days)	30
Corresponding flow present (cfsm)	0.5
Habitat when restored (% WA)	
Rare habitat (%WA)	
Allowable duration under (days)	5
Catastrophic duration (days)	10
Corresponding flow (cfsm)	0.3
Common flow (cfs)	204.6
Critical flow (cfs)	51.15
Rare flow (cfs)	30.69

Spring flood bio-period (March 1 through April 30)

For lack of habitat information no rules, are developed for this season.

For The Upper Souhegan segment, Reach 2 was selected as being the most flow sensitive American shad spawning habitat. Commonly the habitat does not stay under 70% WA for longer than 25 days and duration of 40 days is already catastrophic. This corresponds with flows of 2.1 cfsm (136 cfs). The critical levels begin below 30% WA (0.6 cfsm – 39 cfs) which should not last longer than 10 days. 15 days of habitat under this level is already catastrophic. The rare events are when habitat drops under 35% WA (0.4 cfsm – 24 cfs). Those may last up to 4 days and are catastrophic with duration over 7 days (Table 18).

Table 18. Recommended flow augmentation criteria for spring flood bio-period.

Indicator	GRAF	GRAF	**Recommended flows**	
Gauge (SR#)	16-18	31-34	25	USGS
Watershed area (mi^2)	64.6	139	102.3	171
Location	**Reach 2**	**Reach 5**	**Upper**	**Lower**
Common habitat (% WA)	**70**	**80**		
Allowable duration under (days)	25	15	25	15
Catastrophic duration (days)	40	25	40	25
Corresponding flow present (cfsm)	2.1	1	2.1	1.0
Critical habitat (% WA)	**30**	**40**		
Allowable duration under (days)	10	5	10	5
Catastrophic duration (days)	15	10	15	10
Corresponding flow present (cfsm)	0.6	0.4	0.6	0.6
Rare habitat (% WA)	**35**	**35**		
Allowable duration under (days)	4	5	4	5
Catastrophic duration (days)	7	10	7	10
Corresponding flow (cfsm)	0.37	0.35	0.37	0.5
Common flow (cfs)	136	139	136	178
Critical flow (cfs)	39	56	45	96
Rare flow (cfs)	24	49	32	88

For the Lower Souhegan Reach 5 was selected as the one with the most flow sensitive American shad spawning habitat. Commonly the habitat does not stay under 80% WA for longer than 15 days and duration of 25 days is already catastrophic. This corresponds with flows of 1 cfsm (139 cfs). The critical levels begin below 40% WA (0.4 cfsm – 56 cfs) which should not last longer than 5 days. 10 days of habitat under this level is already catastrophic. The rare events are when habitat drops under 35% (0.11 cfsm – 15 cfs). Those may last up to 5 days and are catastrophic with duration over 10 days (Table 18).

Recommendation

For the Upper Souhegan, the flows should not commonly fall under 2.1 cfsm (136 cfs) for longer than 25 days, nor under 0.6 cfsm (45 cfs) for 10 days, nor under 0.4 cfsm (32 cfs) for 4 days. This rule should not be violated more often than once in 3 years. Catastrophic durations for these levels are 40, 15, and 7 days, respectively.

For the Lower Souhegan the flows should not commonly fall under 1 cfsm (178 cfs) for longer than 25 days, nor under 0.6 cfsm (96 cfs) for 5 days, nor under 0.5 cfsm (88 cfs) for 5 days. This rule should not be violated more often than once in 3 years. Catastrophic durations for these levels are 25, 10, and 10 days, respectively. Table 18 presents distribution of these flows in reaches as computed using the concurrent flow power functions.

GRAF spawning bio-period (May 1 through June 15)

For the Upper Souhegan segment, Reach 2 was selected as providing the most flow sensitive GRAF spawning habitat. Commonly the habitat does not stay under 30% WA for longer than 20 days and duration of 27 days is already catastrophic. This corresponds with flows of .23 cfsm (15 cfs). The critical levels begin below 10% WA (0.11 cfsm – 7 cfs) which should not last longer than 10 days. 20 days of habitat under this level is already catastrophic. The rare events are when habitat drops under 5% WA (0.4 cfsm – 24 cfs). Those may last up to 4 days and are catastrophic with duration over 7 days (Table 19).

Table 19. Recommended flow augmentation criteria for GRAF spawning bio-period.

Indicator	GRAF	GRAF	**Recommended flows**	
Gauge	16-18	31-34	25	USGS
Watershed area	64.6	139	102.3	171
	Reach 2	**Reach 5**	**Upper**	**Lower**
Common habitat (% WA)	**30**	**10**		
Allowable duration under (days)	20	17	20	17
Catastrophic duration (days)	27	25	27	25
Corresponding flow present (cfsm)	0.23	0.11	0.23	0.23
Critical habitat	**10**	**5**		
Allowable duration under (days)	10	13	10	13
Catastrophic duration (days)	20	23	20	23
Corresponding flow present (cfsm)	0.11	1.4	0.11	1.4
Rare habitat (%WA)	**5**	**4**		
Allowable duration under (days)	10	10	10	10
Catastrophic duration (days)	15	10	15	10
Corresponding flow (cfsm)	0.08	1.9	0.08	1.9
Common flow (cfs)	15	15	22	39
Critical flow (cfs)	7	195	13	239
Rare flow (cfs)	5	264	11	325

For the Lower Souhegan, Reach 5 was selected as the with the most flow sensitive GRAF spawning habitat. Commonly the habitat does not stay under 10% WA for longer than 17 days and duration of 25 days is already catastrophic. This corresponds with flows of 0.11 cfsm (15 cfs). The critical levels begin below 5% WA (1.4 cfsm – 195 cfs) which should not last longer than 13 days. 23 days of habitat under this level is already catastrophic. The rare events are when habitat drops under 4% (1.9 cfsm – 264 cfs). Those may last up to 10 days and are catastrophic with duration over 10 days (Table 11).

Recommendation

As presented earlier, during early summer the spawning habitat for GRAF species mostly declines with flow increase. Therefore on this bio-period the recommendations are different than for other seasons. It is recommended to target flow levels and durations rather than downward limitations of flows.

For the Upper Souhegan the flows should commonly last under 0.23 cfsm (22 cfs) for 20 days, but not below 0.08 cfsm (11 cfs) for more than 10 days, This rule should not be violated more often than once in 3 years. Catastrophic durations are if flows stay under 11 cfs for longer than 15 days.

For the Lower Souhegan the flows should stay under 0.2 cfsm (39 cfs) for at least 17 days, but no longer than 25 days. It should not be above 1.4 cfsm (239 cfs) for longer than 13 days (23 days in catastrophic case). The flows should not be higher 1.9 cfsm (325 cfs) for longer than 10 days. Catastrophic durations for these two levels are 10 days or more.

Discussion

Analysis of fish fauna status indicated that the fish community was affected mostly by high water temperatures and poor water quality. Temperature and pollution intolerant species are strongly underrepresented or missing in the existing fish community. Other than juvenile Atlantic salmon, diadromous species are absent in the Souhegan River. The physical habitat was not a limiting factor for diadromous species to the extent that would justify their absence. In contrary, American eel had greater habitat availability than all other species in the Upper Souhegan. There were high amounts of available spawning habitat for American shad in the Upper Souhegan, but (with exception of Reach 2) less for Atlantic salmon. Juvenile Atlantic salmon habitat was well represented in the upper most reaches (Reach 1 and 2). This is essential considering all of the effort invested in the restoration of these species. Brook trout and slimy sculpin also have available habitat in the Upper Souhegan, which could be strongly improved through restoration measures. These fish were not sampled in the Upper Souhegan and their absence can be explained by the summer water temperatures, which almost consistently stayed above the lethal levels for these species.

In general the community structure of the resident fauna corresponded with the target community for the Souhegan River, however the in the Upper Souhegan the proportions of fluvial dependant and generalist species is lower than in the TFC. Particularly, an under representation of white sucker is apparent. In the Upper River it may be caused by low amounts of physical habitat, which for white sucker and common shiner occurs in similar ratio as the proportions of fish found in the sample. The habitat availability increases with flow and could be improved with tested restoration measures. In the Lower Souhegan white sucker is also underrepresented but the reasons may be different as the proportions of habitat are higher than observed. It is also unlikely caused by lack of habitat for juvenile and larval fish, because YOY habitat was found in large quantities in the entire river. Abundant spawning habitat was also found, most notably for white sucker. However, the majority of the white sucker spawning habitat occurs in the Upper Souhegan, upstream of Wilton, an area not accessible for individuals from the lower river because of numerous dams. White sucker is known for long spawning migration and could be easily limited by this habitat fragmentation. Moreover instantaneous flow fluctuations connected to hydropower generation were observed on the Souhegan River during the period of study and it is recommended that such fluctuations be avoided during the spawning bio-period. White sucker are broadcast spawners with long incubation times, and therefore may not get the required gestation period if eggs are exposed to air through flow fluctuations.

As mentioned before, common shiner is also under represented in the Upper River and, similarly to white sucker, the habitat proportions correspond with fish proportions in the community. In the lower river, however, the abundance of this species is higher than expected, which corresponded well with relatively abundant spawning habitat for this species. Because spawning requirements of common shiner are not as stringent as those of white sucker this observation further supports the previously mentioned conclusions.

These investigation documented that the overall fish abundances were low. The R&G habitat for GRAF species usually comprised less than one third of the wetted area. This could be improved with simple restoration measures such as adding woody debris and canopy cover. It is expected that the physical habitat at these levels is not the only limiting factor; however it may lower the ability of fish fauna to resist the stress caused by high temperatures.

Although fish habitat is not overabundant; it is stable over the range of the investigated flows. Only in the Upper Souhegan did the rating curves document flow sensitivity of habitat, particularly at the low flow conditions. This is an important consideration for the Souhegan River because historic records exhibited a high frequency of very low flows in the summer and fall. Even simulated flow time series exhibit the same pattern, particularly during the summer and early fall seasons. Therefore, the maintenance of appropriate frequency and duration of such flow events is important and may require some directed flow releases that would bring the habitat from the rare to common level. In early summer (June 15 to July 15) lower flows may actually support resident fauna spawning efforts, which would allow water to be stored for augmentation later in the summer. The augmentation flows are usually not very high, and maybe needed for a short period of time to create relief for the stressed fauna. During the performance of this study, relatively high levels of mussel and odonate habitat in the Lower Souhegan was identified. Mussel habitat did not appear to be flow sensitive (instead preferring fine substrates) and was therefore not presented in the rating curves. Reach 5 was the richest in this fauna in terms of found individuals as well as habitat. The odonate habitat is flow sensitive with a preference to lower flows.

In general Reaches 2 and 5 were of the highest habitat quality for investigated fauna. Reach 2 had a particularly high amount of spawning habitat. Reach 3 exhibited the highest level of impairment. Beginning with Reach 6 the character of the river changed to one more suitable for generalist species, hence the habitat quantity and quality gradually dropped.

Table 20 presents a score card of recommended priority management areas for the Souhegan River by reaches. the most important management issue at this time is a reduction of the thermal impact caused by upstream impoundments. This can be accomplished by improvements at the source (reservoir structure modifications) and by increasing resilience of aquatic fauna through favorable physical habitat. The primary measures are to secure more natural frequency and duration of favorable habitat levels (pulsed flow augmentation) as well as by increasing the diversity and richness of habitat structure (channel improvements by adding large woody debris, shading ,and defragmentation).

Table 20: The priority and importance of various aspects for maintenance and restoration of the aquatic fauna. Red indicates critical issues or areas. Yellow indicates areas of concern. Green indicates the reaches with the highest habitat quality.

	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7
Temperature and Water Pollution							
Flow Augmentation							
Fish Passage							
Stream Improvements							

Part 2. Ability of the Existing System to Meet PISF Goals

Part 2. Hydrographs

I.) Representative Hydrographs

Daily streamflow data for the Souhegan River were determined using United States Geological Survey (USGS) Merrimack gage (gage no. 01094000) streamflow data in the lower Souhegan. The gage is located just upstream of the Souhegan River confluence with the Merrimack River, at the head of Wildcat Falls. The Souhegan River gaging station was inactive from Water Year 1977 to 2001. The nearby Stony Brook gage was used to estimate Souhegan flows for the missing time period.

Streamflow values at 10 locations upstream of the USGS gage (see Table 21) were estimated from concurrent flow measurements that were conducted for flows ranging from 0 to 1 cfsm. Measured flows were scaled by watershed area to determine flow values in cfsm and then correlated to the USGS measured flows (also converted to cfsm). Given the relatively close proximity of some study reaches, four lumped relationships were developed from combined concurrent flow measurements at two neighboring locations. Representative hydrographs were developed for the following scenarios: last five years, wet three years, average three years, and dry three years. A 30-year hydrograph was developed to aid with the development of the CUT curves for fisheries habitat. Details of how the periods were developed may be found in Appendix 3. The representative hydrographs are presented by reach in Figure 44.

The streamflow record from water years 1910 to 2004 was used to identify the three-year periods having wet, dry, and average conditions. In addition, streamflow values for the last five years and a 30-yr period were identified. Three-year average streamflow values were determined using a three-year moving window. When available, the annual precipitation record was examined to support the selection of three-year periods. The maximum average flow (376.0 cfs) occurred from 1951 to 1953 and had a correspondingly high precipitation value of 48.4 in. The minimum average flow (154.4 cfs) occurred from 1964 to 1966 and was preceded by the lowest average annual precipitation (31.8 in) from 1963 to 1965. Average conditions (283.1 cfs) were found from 1994 to 1996. Similar average streamflow also occurred from 1945-1947 (284.8 cfs). The latter will be used as the 1945 to 1947 data were measured while the 1994 to 1996 data were estimated from the Stony Brook gage data. The average streamflow over the last five years (262.8 cfs) was slightly below the long-term average conditions. The selected 30-yr period is 1948 to 1977. This period includes historical wet and dry periods and has an average flow (286.5 cfs) that is close to the long-term average.

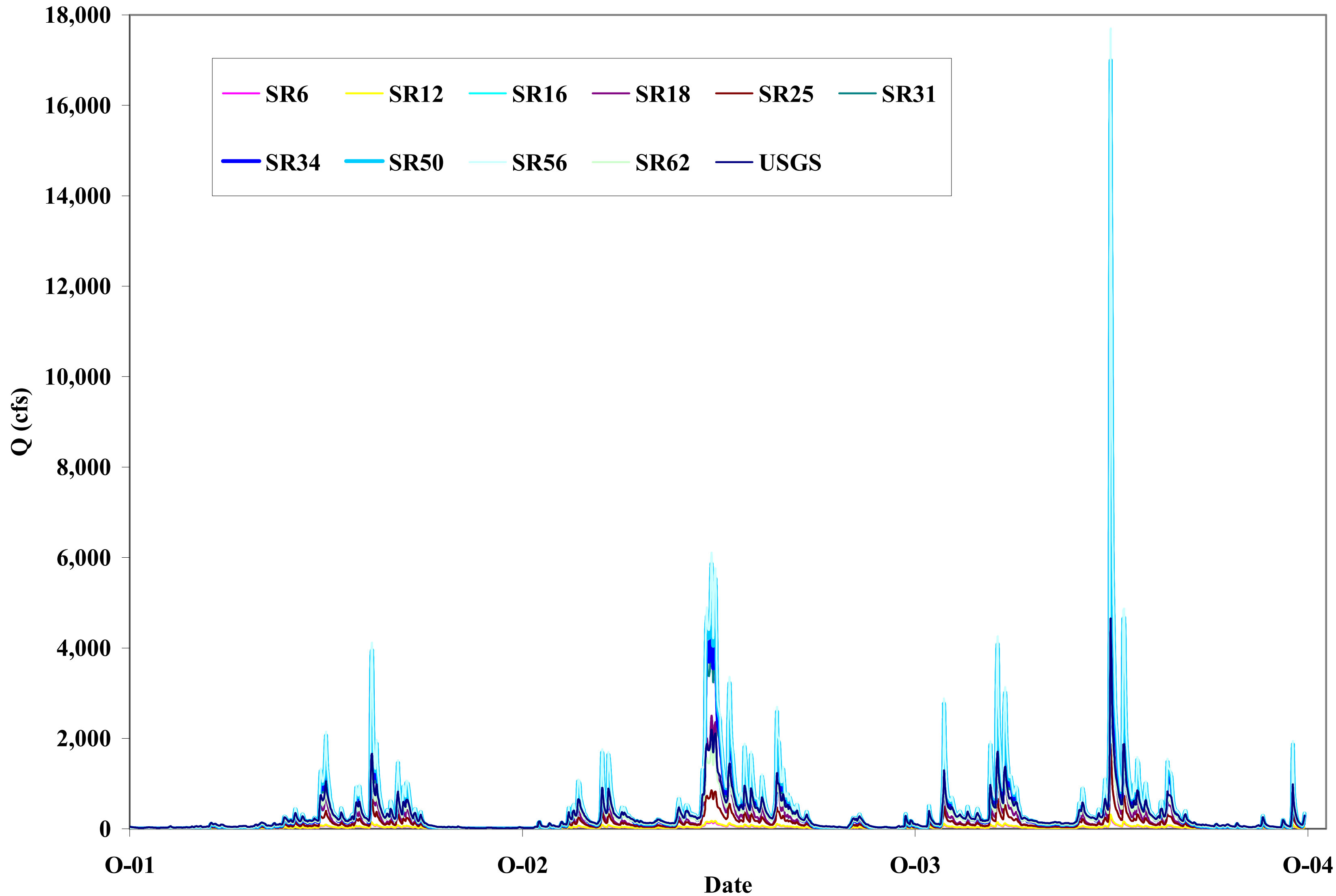
The representative hydrographs include the historic net withdrawals (withdrawal minus return flow) in the watershed upstream of the Merrimack gage. To consider the impact of AWU withdrawals, net of return flow, a monthly record of net withdrawals was created. Here, all long term water use data from AWUs, not just direct and induced recharge, are considered.

These withdrawals include groundwater pumping values and the historic surface water withdrawals. Documented return flows were also included. Average values from 2000-2004 were used to estimate monthly gross and net water use for each AWU. Net water use (equivalently consumptive water use) was estimated by multiplying the gross use by a consumptive loss rate. Values were summarized by stream reach and used to create monthly losses by reach. The resulting withdrawal minus return flow (cfsm) monthly values are added to the representative hydrographs for each reach to generate streamflow records without the impact of AWUs withdrawals.

Table 21. Concurrent flow results for locations upstream of the Souhegan River USGS gage using the relationship $Q_{upstream,\ cfsm} = a\ .Q_{USGS,\ cfsm}{}^{b}$. Concurrent flows were measured from 0 to 1 cfsm. Accuracy of relationships decrease outside the measured range.

Site	Description	Area (mi^2)	Ratio to USGS gage	Num. of Measures	a	b	R^2
SR6	Handicap Access Fish Ramp - Greenville	33.9	0.198	4	0.6078	0.7774	0.962
SR12	High Energy Bank - Greenville	37.0	0.216	4	0.6307	0.7819	0.731
SR6/SR12				8	0.6189	0.7793	0.830
SR16	Upstream of Monadnock Water	64.6	0.377	3	1.0478	1.599	0.995
SR18	Intervale Road - Wilton	65.0	0.379	2	0.8505	1.2962	1.000
SR16/18				5	0.9437	1.4540	0.984
SR25	Wilton wastewater pumping station	102.3	0.597	4	0.5947	1.0369	0.824
SR31	Shopping Center Mall - Milford	127.2	0.743	3	0.964	1.3287	0.991
SR34	Electric Substation - Milford	139.4	0.814	3	1.0151	1.4825	0.984
SR31/34				6	0.996	1.4159	0.981
SR50	Boston Post Road - Amherst	159.0	0.928	3	0.9573	1.3073	0.979
SR56	Tomalison Farm - Amherst	165.6	0.967	3	0.9726	1.3207	0.996
SR50/56				6	0.9649	1.314	0.987
SR62	Turkey Hill Road – Amherst	169.4	0.989	2	0.8233	1.0098	1.000
USGS	USGS Gage	171.3	1.000	N/A	N/A	N/A	N/A

Figure 44. Representative hydrograph by reach, for the last five years.



II.) Comparison of PISF to Representative Hydrographs

All recommended PISFs were compared to the untransformed representative hydrographs. This comparison then demonstrates how the existing system, including withdrawals and return flows, meets the PISFs.

Recreation

The recommended PISF for recreation is 4cfsm in Reaches 1 and 2 and no recommended PISF downstream of Reach 2. These comparisons are coarse estimates since the regression equations were calibrated only up to 1 cfsm. Table 22 delineates the number of days that the representative hydrographs meet the recreation PISF.

Table 22. Comparison of Existing System Streamflow to the Recreation PISF. (number of days per year the reach meets the PISF and fraction of time in the representative hydrograph).

Representative Hydrograph	Reach 1		Reach 2	
	Days	%	Days	%
Last five years	10	0.68	228	15.6
Wet three years	19	1.74	309	28.2
Average three years	4	0.37	198	18.1
Dry three years	0	0.00	94	8.6

Fishing

The recommended fishing PISF Use is dependent on the Souhegan River flow only to the extent that it protects the fishery resource. Therefore this section defers the PISF to that for fish habitat.

Hydropower

The hydropower PISF is 0.7 cfsm in Reach 1 and 0.44 cfsm in Reach 3. No other hydropower PISF are specified. Table 23 delineates the number of days that the representative hydrographs meet the hydropower PISF.

Pollution Abatement

The pollution abatement PISF is 0.1 cfsm for all Reaches. Table 24 delineates the number of days that the representative hydrographs do not meet the pollution abatement PISF. The wet hydrographs demonstrates more times when the flow falls below 0.1 cfsm than the average hydrograph. This is because there were dry periods at the very start and very end of the wet hydrograph.

Table 23. Comparison of Existing System Streamflow to the Hydropower PISF. (number of days per year the reach meets the PISF and fraction of time in the representative hydrograph).

Representative Hydrograph	Reach 1		Reach 3	
	Days	%	Days	%
Last five years	561	17.9	520	35.6
Wet three years	590	53.9	570	52.1
Average three years	479	43.7	624	57.0
Dry three years	267	24.4	351	32.0

Table 24. Comparison of Existing System Streamflow to the Pollution Abatement PISF. (number of days per year each reach does not meet the PISF and fraction of time in the representative hydrograph).

Representative Hydrograph	Reach 1		Reach 2		Reach 3		Reach 4	
	Days	%	Days	%	Days	%	Days	%
Last five years	28	1.9	204	14.0	165	11.3	187	12.2
Wet three years	0	0.0	111	10.1	50	4.6	72	6.6
Average three years	0	0.0	8	0.7	1	0.1	3	0.3
Dry three years	212	19.3	442	40.3	369	33.7	411	37.5

Representative Hydrograph	Reach 5		Reach 6		Reach 7		Reach 8	
	Days	%	Days	%	Days	%	Days	%
Last five years	187	12.8	163	11.2	163	11.2	33	2.3
Wet three years	72	6.6	50	4.6	50	4.6	0	0.0
Average three years	3	0.3	1	0.1	1	0.1	0	0.0
Dry three years	411	37.5	369	33.7	369	33.7	219	20.0

Water Supply

Water supplies do not have recommended PISF.

RTE: Fish, wildlife, vegetation, and natural/ecological communities

A. Rare, Threatened, and Endangered Wildlife

Wood Turtle (Clemmys insculpta)

The summer PISF for the Wood Turtle are flows less that 5.85 cfsm in Reaches 7 and 8 from June through September. In the winter, the December through February flow should exceed the previous minimum November flow, also in Reaches 7 and 8.

Table 25. Comparison of Existing System Streamflow to the Wood Turtle PISF. (number of days per year each reach does not meet the PISF and fraction of time in the representative hydrograph). The majority of the winter PISF failures are due to lower flows in late February in the five year record.

Summer

Representative Hydrograph	Reach 7		Reach 8	
	Days	**%**	**Days**	**%**
Last five years	4	1.1	0	0.0
Wet three years				
Average three years				
Dry three years				

Winter

Representative Hydrograph	Reach 7		Reach 8	
	Days	**%**	**Days**	**%**
Last five years	67	18.4	67	18.4
Wet three years				
Average three years				
Dry three years				

Fowlers Toad (Bufo fowleri)

Pied-Billed Grebe (Podolymbus podiceps)

Osprey (Pandion haliaetus)

Common Loon (Gavia immer)

B. Rare, Threatened, and Endangered Plants

Long's Bitter Cress (Cardamine longii Fern.)

Wild Garlic (Allium canadense)

Wild Senna (Cassia hebecarpa)

C. Natural Communities

High Energy Riverbank (Twisted Sedge (Carex torta) Low Riverbank and Fern Glade)

Southern New England Floodplain Forest: Silver Maple (Acer saccharinum) Floodplain Forest

Southern New England Floodplain Forest: Sycamore (Platanus occidentalis) Floodplain Forest

Oxbow/Backwater Marsh

Environmental/Fish Habitat

R&G Bio-Period

Atlantic Salmon Spawning Bio-period (October 1 through November 15)

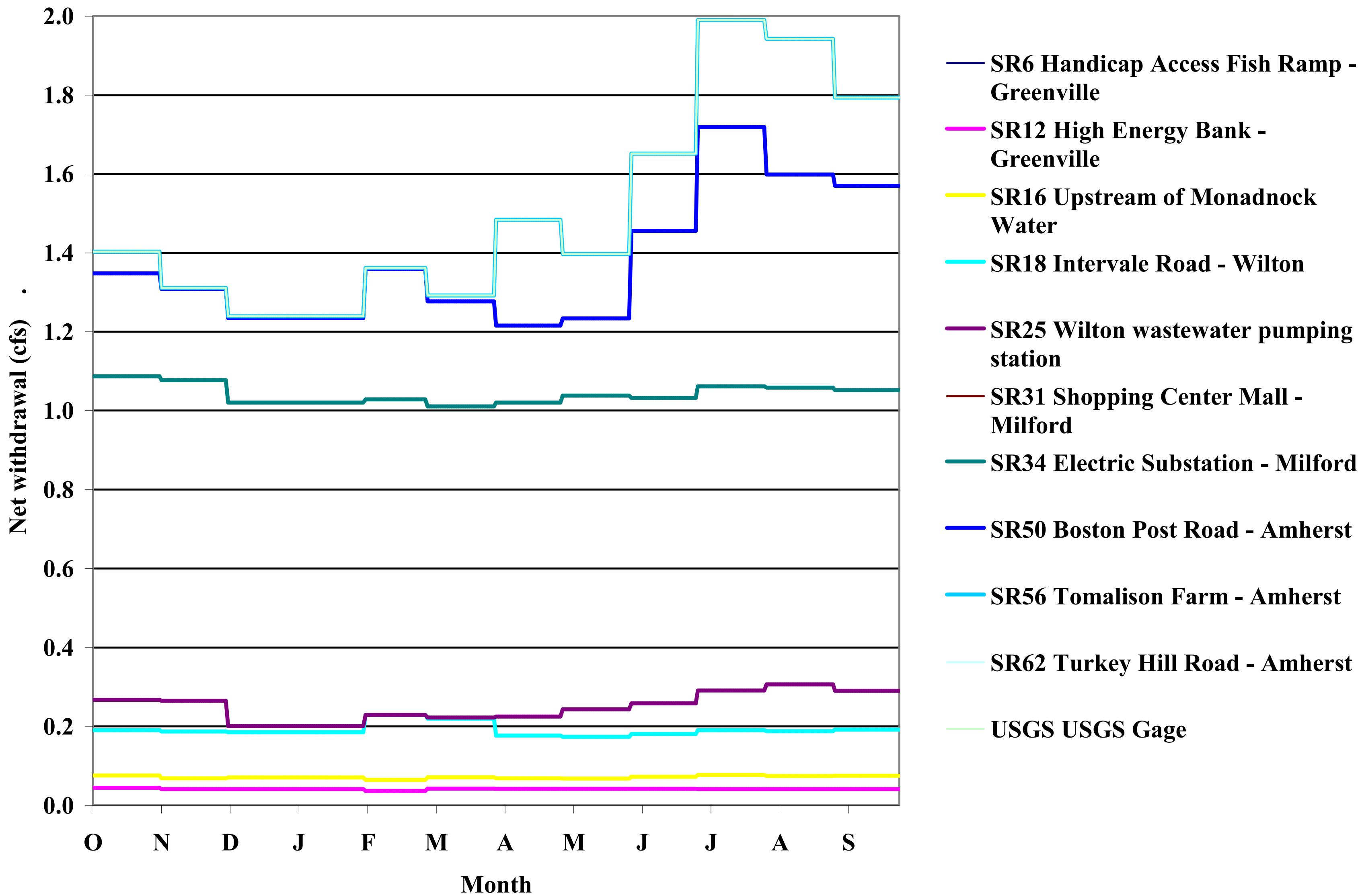
Overwintering Bio-period (November 15 through February 28)

Spring Flood Bio-period (March 1 through April 30)

GRAF spawning bio-period (May 1 through June 15)

Representative Hydrograph	Reach 1		Reach 2	
	Days	**%**	**Days**	**%**
Last five years				
Wet three years				
Average three years				
Dry three years				

Figure 45. Monthly net withdrawal minus return flow (cfs). Values are to be added to the 5-year hydrograph for each reach.



III.) Water Quality Standards

As part of NH DES's biennial 305(d)/303(d) reporting to the USEPA, an assessment of compliance with water quality standards is made for all waters of the state, including the Souhegan River. Although these reports indicate that the Souhegan generally meets most water quality criteria, there are specific non-compliance areas that are noted in both the 305(d) and 303(d) reports. The 305(d) report describes the extent to which water quality meets the designated use criteria while the 303(d) report lists waters that are impaired or threatened and require a Total Maximum Daily Load (TMDL) study.

First, all waters of the state are listed as non-supporting of aquatic life because of mercury, the includes then the Souhegan. Second, portions of the Souhegan River above the confluence with Stony Brook are listed as non-supporting of aquatic life due to pH, aluminum, and macroinvertebrate and bioassessment criteria. In addition, a portion of this section is also listed as non-supporting of primary contact recreation due to E. coli bacteria. Finally, the lower section of the Souhegan River is listed as threatened for aquatic life due to copper.

For upper river listings, pollutant sources are unknown. Furthermore, it does not appear that the non-supporting status here is flow related. Rather, the causes of non-compliance are related to atmospheric deposition, acid rain and perhaps non-point sources. Therefore, we conclude that PISF values are unrelated to existing water quality in the upper river, except for the 7Q10 PISF used to regulate the Greenville wastewater discharge, which itself appears to be unrelated to the non-supporting listings.

However, in the lower section of the Souhegan River where the State considers aquatic life to be threatened by copper, the source of copper is listed as "municipal discharges". The Milford NPDES permit has specific limits for copper in its discharge and these limits are by regulation based on 7Q10 flow. Thus, the pollution abatement PISF of 7Q10 is equally applicable to protection of designated uses as for compliance with specific water quality criteria.

Review of the hydrologic data for the Souhegan River for the last five years indicates that streamflow as measured or estimated at the USGS gage dropped below the computed 7Q10 value of 13 cfs on only three days during the five-year period of evaluation– August 29, 30 and 31, 2001 – and only to 12, 11 and 12 cfs, respectively. Lower than normal flow conditions were experienced throughout New Hampshire in August 2001 due to below normal precipitation received during the late spring and summer. These data suggest that existing flow conditions overwhelmingly met the water quality PISF of 7Q10 flow during the 2000 - 2004 examination period. Even though there could have been a theoretical violation of water quality criteria for three days, Milford would have had to have been discharging at their maximum permit level and this combination of very low flow and maximum discharge seldom happens at most WWTP. Consequently, we would conclude that the existing Souhegan River system largely met the water quality PISF for the period of evaluation.

However, a 7Q10 flow event is by definition a 1 in 10 year event, so it is not unexpected that Souhegan flows during the five year study period did not fall below 7Q10. If a longer flow record were examined, lower flows would be more apparent and in very dry years, flows substantially below 7Q10 could be expected for an extended period of time. Furthermore, as evidenced by the presented hydrologic analysis, affected water users have historically (last five years) been reducing the streamflow in the lower Souhegan by 1 to 2 cfs or 10 – 15% of 7Q10, depending on location. Although streamflows will naturally flow below 7Q10 periodically, the data suggests that water users are likely causing streamflows to fall below natural 7Q10 levels more frequently than 1 every 10 years. Consequently, it is concluded that for the lower section of the Souhegan (i.e. from the Milford WWTP to the Merrimack River), the existing system does not meet the water quality PISF and that mitigation should be investigated.

IV.) Discussion of how the proposed PISF values meet the criteria in RSA 483:1 and 483:2 and water quality standards

V.) Preliminary determination of Designated River Reaches

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Whitworth, 1996. Freshwater Fishes of Connecticut

Appendices

Appendix 1

Affected Dam Owners (ADOs)

Dam Name: Burton Pond Dam
Dam Code: 147.17
Location: Lyndeborough
Owner: SNVK LLC
Address: 1020 Isaac Frye Highway/PO Box 1208, Wilton, NH 03086
Contact: Barbara Woodward
Phone: 603-654-5351
Email:

River/Waterbody: Tributary of Stony Brook **Lat/Lon:** 42.5202, -71.4847

Status: Active

Year Built or Rebuilt: 1846

Owner Classification: Private

Construction Material: Earth

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
160		40	14	0.46	350	300		75		

Emergency Spill: N **Drop Inlet: N** **Uncontrolled Spill: Y**
Stoplogs: N **Gate: N** **Pond Drain: N**

National ID#: NH00175

Main Use of Dam: Recreation

Hazard Class: A

Dam Name: Canal Dam/Dye House Dam
Dam Code: 254.04
Location: Wilton
Owner: Label Arts Inc
Address: One Riverside Way, Wilton, NH 03086
Contact: Paul Tardiff
Phone: 603-654-6131
Email:

taken July 1975

River/Waterbody: Souhegan River **Lat/Lon:** 42.5029, -71.4421

Status: Active

Year Built or Rebuilt: 1876

Owner Classification: Private

Construction Material: Earth

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
500	4	3	15	29.8						

Emergency Spill: **Drop Inlet:** **Uncontrolled Spill:**

Stoplogs: **Gate:** **Pond Drain:**

National ID#: NH03407

Main Use of Dam: Recreation

Hazard Class: AA

Dam Name: Chamberlain Falls Dam/Souhegan River III Dam

Dam Code: 101.03
Location: Greenville
Owner: Chamberlain Falls Hydro
Address: 773 Greenville Road, Mason, NH 03048
Contact: Alden T. Greenwood
Phone: 603-878-2485
Email:


taken 6/10/05

River/Waterbody: Souhegan River **Lat/Lon:** 42.4607, -71.4838

Status: Active

Year Built or Rebuilt: 1876

Owner Classification: Private

Construction Material: Stone/concrete/masonry

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
82	5	0.5	20	35	4	2.5				

Emergency Spill: **Drop Inlet:** N **Uncontrolled Spill:**
Stoplogs: **Gate:** **Pond Drain:**

National ID#: NH02007

Main Use of Dam: Hydroelectric

Hazard Class: AA

Dam Name: Dream Lake Dam
Dam Code: 007.15
Location: Amherst
Owner: Melio Riccitelli
Address: Dream Lake Drive, Amherst, NH 03031
Contact:
Phone:
Email:

River/Waterbody: Natural swale **Lat/Lon:** 42.5209, -71.3612

Status: Active

Year Built or Rebuilt: 1966

Owner Classification: Private

Construction Material: Concrete/earth embankment

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
50		10.4	6.5	0.25	36.24	15.44				

Emergency Spill: **Drop Inlet:** **Uncontrolled Spill:**
Stoplogs: **Gate:** **Pond Drain:**

National ID#: NH01172

Main Use of Dam: Recreation

Hazard Class: AA

Dam Name: Goldman Dam
Dam Code: 159.02
Location: Milford
Owner: Public Works Department
Address: 289 South Street, Milford, NH 03055
Contact:
Phone: 603-673-1662
Email:

River/Waterbody: Souhegan River **Lat/Lon:** 42.5013, -71.3855

Status: Active

Year Built or Rebuilt: 1931

Owner Classification: Public

Construction Material: Concrete

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
180	5.2	8	12	137.8	112	18	8760	7364	7364	10500

Emergency Spill: N **Drop Inlet: N** **Uncontrolled Spill: Y**
Stoplogs: N **Gate: N** **Pond Drain: N**

National ID#: NH00312

Main Use of Dam: Recreation

Hazard Class: A

Dam Name: Souhegan River Dam/High Bridge Dam
Dam Code: 175.10
Location: New Ipswich
Owner: Warwick Mills Inc
Address: 301 Turnpike Road, New Ipswich, NH 03071
Contact: Maureen MacAdams
Phone: 603-878-1565 ext 254
Email:

taken 6-28-04

taken 6-28-04

River/Waterbody: Souhegan River **Lat/Lon:** 42.4504, -71.4941

Status: Active

Year Built or Rebuilt: pre 187 **Owner Classification:** Private

Construction Material: Concrete

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
86	10.5		15	10						

Emergency Spill: N **Drop Inlet: N** **Uncontrolled Spill: Y**
Stoplogs: N **Gate: Y** **Pond Drain: Y**

National ID#: NH02699

Main Use of Dam: Recreation **Hazard Class:** AA

Dam Name: Joe English Pond Dam
Dam Code: 007.01
Location: Amherst
Owner: US Air Force Station New Boston
Address: NH Satellite Tracking Station, New Boston, NH 03070
Contact: Steve Najar
Phone: 603-471-2426
Email:

taken 1939

taken 1939

River/Waterbody: Joe English Brook **Lat/Lon:** 42.5605, -71.3806

Status: Active

Year Built or Rebuilt: Pre 1935

Owner Classification: Federal

Construction Material: Earth/Stone

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	Sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
95	1.5	36	5.5	3.13	101	47	427	144	144	

Emergency Spill: N **Drop Inlet: N** **Uncontrolled Spill: Y**
Stoplogs: N **Gate: N** **Pond Drain: N**

National ID#: NH01165

Main Use of Dam: Recreational

Hazard Class: AA

Dam Name: Lincoln Pond Dam
Dam Code: 007.04
Location: Amherst
Owner: Lincoln Pond Association
Address: 24 Old Manchester Road, Amherst, NH 03031-1722
Contact: Peter Foley
Phone:
Email:

River/Waterbody: Tributary of Joe English Brook **Lat/Lon:** 42.5316, -71.3625

Status: Active

Year Built or Rebuilt: 1916

Owner Classification: Private

Construction Material: Concrete

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	Sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
100		10	6	0.3	33.2	13.2	264	15	15	

Emergency Spill: N **Drop Inlet: N** **Uncontrolled Spill: Y**
Stoplogs: N **Gate: N** **Pond Drain: N**

National ID#: NH01166

Main Use of Dam: Recreation

Hazard Class: AA

Dam Name: Lincoln Pond Dam
Dam Code: 007.04
Location: Amherst
Owner: Lincoln Pond Association
Address: 24 Old Manchester Road, Amherst, NH 03031-1722
Contact: Peter Foley
Phone:
Email:

River/Waterbody: Tributary of Joe English Brook

Lat/Lon: 42.5316, -71.3625

Status: Active

Year Built or Rebuilt: 1916

Owner Classification: Private

Construction Material: Concrete

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	Sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
100		10	6	0.3	33.2	13.2	264	15	15	

Emergency Spill: N **Drop Inlet: N** **Uncontrolled Spill: Y**
Stoplogs: N **Gate: N** **Pond Drain: N**

National ID#: NH01166

Main Use of Dam: Recreation

Hazard Class: AA

Dam Name: McLane Dam
Dam Code: 159.03
Location: Milford
Owner: Town of Milford
Address: 1 Union Square, Milford, NH 03055
Contact: Bill Ruoff
Phone: 603-673-2257
Email:

taken 6-28-04

River/Waterbody: Souhegan River **Lat/Lon:** 42.5009, -71.3846

Status: Active

Year Built or Rebuilt: Pre 1935

Owner Classification: Local government

Construction Material: Concrete


taken 6-28-04

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
200	9.8	3	18.7	138	40	9	8,788	16,718	17,412	10,777

Emergency Spill: **N** **Drop Inlet:** **N** **Uncontrolled Spill:** **Y**

Stoplogs: **Y** **Gate:** **N** **Pond Drain:** **N**

National ID#: NH01081

Main Use of Dam: Recreation

Hazard Class: A

Dam Name: McLane Dam
Dam Code: 159.03
Location: Milford
Owner: Town of Milford
Address: 1 Union Square, Milford, NH 03055
Contact: Bill Ruoff
Phone: 603-673-2257
Email:

taken 6-28-04

River/Waterbody: Souhegan River **Lat/Lon:** 42.5009, -71.3846

Status: Active

Year Built or Rebuilt: Pre 1935

Owner Classification: Local government

Construction Material: Concrete

taken 6-28-04

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
200	9.8	3	18.7	138	40	9	8,788	16,718	17,412	10,777

Emergency Spill: N **Drop Inlet: N** **Uncontrolled Spill: Y**

Stoplogs: Y **Gate: N** **Pond Drain: N**

National ID#: NH01081

Main Use of Dam: Recreation

Hazard Class: A

Dam Name: Merrimack Village Dam
Dam Code: 156.01
Location: Merrimack
Owner: Pennichuk Water Works
Address: 4 Water Street, PO Box 1947, Merrimack NH, 03054-1947
Contact: Chris Countie
Phone: 603-882-5191 ext 53
Email:

taken April 2005

River/Waterbody: Souhegan River **Lat/Lon:** 42.5137, -71.2937

Status: Active

Year Built or Rebuilt: 1907

Owner Classification: Private

Construction Material: Concrete

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	Feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
180	8	12	20.5	171	170	85	10,870	10,260	10,475	13,330

Emergency Spill: N **Drop Inlet: N** **Uncontrolled Spill: Y**

Stoplogs: Y **Gate: Y** **Pond Drain: Y**

National ID#: NH00115

Main Use of Dam: Recreation

Hazard Class: A

Comment: Dam being evaluated for removal.

Dam Name: New Wilton Reservoir Dam
Dam Code: 254.09
Location: Wilton
Owner: Town of Wilton
Address: PO Box 83, Wilton, NH 03086
Contact: Charles McGettigan
Phone: 603-654-9451
Email:

River/Waterbody: Stockwell Brook **Lat/Lon:** 42.5032, -71.4616

Status: Active

Year Built or Rebuilt: 1933

Owner Classification: Municipal/Local government

Construction Material: Concrete

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
123	1.3	22.1	24	0.4	335	240	33.3	105	127	33.3

Emergency Spill: N **Drop Inlet: Y** **Uncontrolled Spill: Y**
Stoplogs: Y **Gate: Y** **Pond Drain: Y**

Type Pipe: Steel

National ID#: NH00261

Main Use of Dam: Water Supply

Hazard Class: B

Dam Name: Osgood Pond Dam
Dam Code: 159.04
Location: Milford
Owner: Town of Milford
Address: 1 Union Square, Milford, NH 03055
Contact: Bill Ruoff
Phone: 603-673-2257
Email:

River/Waterbody: Great Brook

Lat/Lon: 42.4914, -71.3950

Status: Active

Year Built or Rebuilt: 1861

Owner Classification: Municpal/Local government

Construction Material: Stone/earth

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	Feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
150	1.9	24.16	9	5.24	270	57	158.6	581.8	581.8	

Emergency Spill: N **Drop Inlet: N** **Uncontrolled Spill: Y**
Stoplogs: Y **Gate: Y** **Pond Drain: Y**

National ID#:NH00314

Main Use of Dam: Recreation

Hazard Class: A

Dam Name: Otis Falls Dam
Dam Code: 101.01
Location: Greenville
Owner: Alden T Greenwood
Address: 773 Greenville Road, Mason, NH 03048
Contact: Alden Engineering Company
Phone: 603-878-2485
Email:

taken 6-28-04

taken 6-28-04


taken 6-28-04


taken April 2005

River/Waterbody: Souhegan River

Lat/Lon: 42.4600, -71.4847

Status: Active

Year Built or Rebuilt: 1936

Owner Classification: Private

Construction Material: Concrete

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
150		8	27	29.6	105	75		3130		1,885

Emergency Spill: **Drop Inlet:** **Uncontrolled Spill:**

Stoplogs: **Gate:** **Pond Drain:**

National ID#: NH00041

Main Use of Dam: Hydroelectric

Hazard Class: A

Dam Name: Pine Valley Mill Dam
Dam Code: 254.01
Location: Wilton
Owner: Milford Elm Street Trust
Address: PO Box 517, Wilton, NH 03086
Contact: C/O Earthworks Inc
Phone: 603-654-2433
Email:

taken April 2005

River/Waterbody: Souhegan River **Lat/Lon:** 42.5020, -71.4344

Status: Active

Year Built or Rebuilt: 1912

Owner Classification: Private

Construction Material: Concrete

taken 6/28/05

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
200		5	23	97	70	30		11,400		7,550

Emergency Spill: **Drop Inlet:** **Uncontrolled Spill:**

Stoplogs: **Gate:** **Pond Drain:**

National ID#: NH00258

Main Use of Dam: Hydroelectric

Hazard Class: A

Dam Name: Pratt Pond Dam
Dam Code: 175.03
Location: New Ipswich
Owner: Pratt Pond Association
Address: PO Box 241, New Ipswich, NH 03071
Contact: Nancy Redling
Phone: 603-878-4312
Email:

River/Waterbody: Pratt Brook

Lat/Lon: 42.4411, -71.5420

Status: Active

Year Built or Rebuilt: 1890

Owner Classification: Private

Construction Material: Concrete

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
150	1.5	35	6.5	0.74	110	58	47	36	128	

Emergency Spill: N **Drop Inlet: N** **Uncontrolled Spill: N**

Stoplogs: Y **Gate: N** **Pond Drain: N**

National ID#: NH00557

Main Use of Dam: Recreation

Hazard Class: A

Dam Name: Souhegan River Dam
Dam Code: 101.02
Location: Greenville
Owner: Greenville Elderly Housing/Greenville Estates
Address: 54-56 Main Street, Manchester, NH 03101
Contact:
Phone: 603-434-0525
Email:

photo 6/28/04

River/Waterbody: Souhegan River (below High Bridge) **Lat/Lon:** 42.4602, -71.4842

Status: Active

Year Built or Rebuilt: 1856

Owner Classification: Private

Construction Material: Stone/concrete

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
80	5	1.5	15	35	10	5				

Emergency Spill: N **Drop Inlet: N** **Uncontrolled Spill: Y**
Stoplogs: N **Gate: N** **Pond Drain: N**

National ID#: NH02006

Main Use of Dam: Hydroelectric

Hazard Class: AA

Dam Name: Souhegan River III Dam
Dam Code: 254.03
Location: Wilton
Owner: Label Arts Inc
Address: One Riverside Way, Wilton, NH 03086-2000
Contact: Paul Tardiff
Phone: 603-654-6131
Email:

River/Waterbody: Souhegan River

Lat/Lon: 42.5029, -71.4434

Status: Active

Year Built or Rebuilt: 1876

Owner Classification: Private

Construction Material: Concrete

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
240	4	0.7	19.3	70.3	8.5	2	5,457	8,426	13,016	5,457

Emergency Spill: N **Drop Inlet: N** **Uncontrolled Spill: Y**

Stoplogs: Y **Gate: Y** **Pond Drain: Y**

Type Pipe: RCP

National ID#:NH00906

Main Use of Dam: Hydroelectric

Hazard Class: AA

Dam Name: Souhegan River Site 12 A North
Dam Code: 234.16
Location: Temple
Owner: New Hampshire Water Division
Address: PO Box 95, 29 Hazen Drive, Concord, NH 03302-0095
Contact: James Gallagher
Phone: 603-271-3406
Email:

River/Waterbody: Miller Gamble River

Lat/Lon: 42.4758, -71.5015

Status: Active

Year Built or Rebuilt: 1965

Owner Classification: State

Construction Material: Earth

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
1190	18.5	108	37.5	5.6	3310	690	6310	6310	6310	922

Emergency Spill: N **Drop Inlet: N** **Uncontrolled Spill: N**

Stoplogs: N **Gate: Y** **Pond Drain: N**

Type Pipe: RCP

National ID#: NH00878

Main Use of Dam: Flood control

Hazard Class: C

Dam Name: Souhegan River Site 12 A South/Senator Charles W. Tobey Dam
Dam Code: 234.11
Location: Temple
Owner: New Hampshire Water Division
Address: PO Box 95, 29 Hazen Drive, Concord, NH 03302-0095
Contact: James Gallagher
Phone: 603-271-3406
Email:

River/Waterbody: Richardson Brook **Lat/Lon:** 42.4742, -71.4945

Status: Active

Year Built or Rebuilt: 1965

Owner Classification: State

Construction Material: Earth

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
290	8.5	108	33.5	5.6	3,310	690	922	6,310	6,310	922

Emergency Spill: Y **Drop Inlet: Y** **Uncontrolled Spill: N**

Stoplogs: N **Gate: Y** **Pond Drain: Y**

Type Pipe: RCP

National ID#: NH00210

Main Use of Dam: Flood control

Hazard Class: B

Dam Name: Souhegan River Site 13 Dam
Dam Code: 175.20
Location: New Ipswich
Owner: New Hampshire Water Division
Address: PO Box 95, 29 Hazen Drive, Concord, NH 03302-0095
Contact: James Gallagher
Phone: 603-271-3406
Email:

River/Waterbody: Tributary of Souhegan River **Lat/Lon:** 42.4559, -71.5043

Status: Active

Year Built or Rebuilt: 1964

Owner Classification: State

Construction Material: Earth

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
1120	3	10	13.5	0.8	278	13.6	165	1,197	1,197	1,020

Emergency Spill: Y **Drop Inlet: Y** **Uncontrolled Spill: N**

Stoplogs: N **Gate: Y** **Pond Drain: Y**

Type Pipe: CMP

National ID#: NH00432

Main Use of Dam: Flood control

Hazard Class: A

Dam Name: Souhegan River Site 15 Dam
Dam Code: 254.30
Location: Wilton
Owner: New Hampshire Water Division
Address: PO Box 95, 29 Hazen Drive, Concord, NH 03302-0095
Contact: James Gallagher
Phone: 603-271-3406
Email:

taken 6/15/05

River/Waterbody: King Brook **Lat/Lon:** 42.4754, -71.4820

Status: Active

Year Built or Rebuilt: 1963

Owner Classification: State

Construction Material: Earth

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
305		69	13	1.1	708	74		1,040		24

Emergency Spill: Y **Drop Inlet: Y** **Uncontrolled Spill: Y**

Stoplogs: N **Gate: Y** **Pond Drain: Y**

Type Pipe: RCP

National ID#: NH00263

Main Use of Dam: Flood control

Hazard Class: B

Dam Name: Souhegan River Site 19 Dam/South Branch Dam
Dam Code: 175.19
Location: New Ipswich
Owner: New Hampshire Water Division
Address: PO Box 95, 29 Hazen Drive, Concord, NH 03302-0095
Contact: James Gallagher
Phone: 603-271-3406
Email:


taken 6-15-05

River/Waterbody: South Branch Souhegan River **Lat/Lon:** 42.4325, -71.5102

Year Built or Rebuilt: 1962

Owner Classification: State

Construction Material: Earth

taken 6-15-05

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
1250	9.9	25	35.5	11.4	1,650	85.3	234	12,973	16,380	234

Emergency Spill: Y **Drop Inlet: Y** **Uncontrolled Spill: Y**

Stoplogs: N **Gate: Y** **Pond Drain: Y**

Type Pipe: CMP

National ID#: NH00434

Main Use of Dam: Flood control

Hazard Class: C

Dam Name: Souhegan River Site 33 Dam
Dam Code: 254.34
Location: Wilton
Owner: New Hampshire Water Division
Address: PO Box 95, 29 Hazen Drive, Concord, NH 03302-0095
Contact: James Gallagher
Phone: 603-271-3406
Email:


taken 6/17/05

River/Waterbody: King Brook **Lat/Lon:** 42.5140, -71.4458

Status: Active

Year Built or Rebuilt: 1971

Owner Classification: State

Construction Material: Earth


taken 6/17/05

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
510		12	21	1	900	24	1,080	2,100		

Emergency Spill: Y **Drop Inlet: Y** **Uncontrolled Spill: N**

Stoplogs: N **Gate: Y** **Pond Drain: Y**

Type Pipe: RCP

National ID#: NH00265

Main Use of Dam: Flood control

Hazard Class: C

Dam Name: Souhegan River Site 33 Dam
Dam Code: 254.34
Location: Wilton
Owner: New Hampshire Water Division
Address: PO Box 95, 29 Hazen Drive, Concord, NH 03302-0095
Contact: James Gallagher
Phone: 603-271-3406
Email:


taken 6/17/05

River/Waterbody: King Brook **Lat/Lon:** 42.5140, -71.4458

Status: Active

Year Built or Rebuilt: 1971

Owner Classification: State

Construction Material: Earth

taken 6/17/05

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
510		12	21	1	900	24	1,080	2,100		

Emergency Spill: Y **Drop Inlet: Y** **Uncontrolled Spill: N**

Stoplogs: N **Gate: Y** **Pond Drain: Y**

Type Pipe: RCP

National ID#: NH00265

Main Use of Dam: Flood control

Hazard Class: C

Dam Name: Souhegan River Site 35 Dam/Smithville Dam
Dam Code: 175.21
Location: New Ipswich
Owner: New Hampshire Water Division
Address: PO Box 95, 29 Hazen Drive, Concord, NH 03302-0095
Contact: James Gallagher
Phone: 603-271-3406
Email:


Taken 6/10/05

River/Waterbody: West Branch Souhegan River **Lat/Lon:** 42.4404, -71.5243

Status: Active

Year Built or Rebuilt: 1965

Owner Classification: State

Construction Material: Earth


Taken 6/10/05

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
1209	4.6	24.9	30	6.4	647	37	12,670	9,135	9,135	1,306

Emergency Spill: Y **Drop Inlet: Y** **Uncontrolled Spill: Y**
Stoplogs: N **Gate: Y** **Pond Drain: Y**

Type Pipe: RCP

National ID#: NH00435

Main Use of Dam: Flood control

Hazard Class: C

Dam Name: Souhegan Site 8 Cemetery Dike/James AG Putnam Dam
Dam Code: 147.36
Location: Lyndeborough
Owner: New Hampshire Water Division
Address: PO Box 95, 29 Hazen Drive, Concord, NH 03302-0095
Contact: James Gallagher
Phone: 603-271-3406
Email:

River/Waterbody: Tributary to Souhegan River **Lat/Lon:** 42.5255,-71.4558

Status: Active

Year Built or Rebuilt: 1977

Owner Classification: State

Construction Material: Earth

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
375		0	16	4.44	307	253				844

Emergency Spill: **Drop Inlet:** **Uncontrolled Spill:**
Stoplogs: **Gate:** **Pond Drain:**

National ID#: NH01073

Main Use of Dam: Flood control

Hazard Class: A

Dam Name: Souhegan Site 8 Dam/James AG Putnam Dam
Dam Code: 147.28
Location: Lyndeborough
Owner: New Hampshire Water Division
Address: PO Box 95, 29 Hazen Drive, Concord, NH 03302-0065
Contact: James Gallagher
Phone: 603-271-3406
Email:

River/Waterbody: Furnace Brook **Lat/Lon:** 42.5307, -71.4608

Status: Active

Year Built or Rebuilt: 1977

Owner Classification: State

Construction Material: Concrete/earth

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
570	9	40	25	4.7	2,721	180		7,140	7,140	77.5

Emergency Spill: Y **Drop Inlet: Y** **Uncontrolled Spill: Y**

Stoplogs: Y **Gate: Y** **Pond Drain: Y**

Type Pipe: RCP

National ID#: NH00474

Main Use of Dam: Flood control

Hazard Class: C

Dam Name: Stoney Brook Dam
Dam Code: 254.05
Location: Wilton
Owner: Town of Wilton
Address: PO Box 83, Wilton, NH 03086
Contact: Charles McGettigan
Phone: 603-654-9451
Email:

taken 6-28-04

River/Waterbody: Stony Brook **Lat/Lon:** 42.5040, -71.4421

Status: Active

Year Built or Rebuilt: 1837

Owner Classification: Municipal/Local government

Construction Material: Concrete/Masonry


taken 6-28-04

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
85	10	2	20	33.5	23.6	3.6	2,130	5,692	5,692	2,611

Emergency Spill: N **Drop Inlet: N** **Uncontrolled Spill: Y**

Stoplogs: N **Gate: N** **Pond Drain: N**

National ID#: NH00260

Main Use of Dam: Recreation

Hazard Class: AA

Dam Name: Swartz Pond Dam
Dam Code: 147.31
Location: Lyndeborough
Owner: Hermon and Dorothy Swartz
Address: 12 Minola Road, Lexington, MA 02173
Contact:
Phone: 617-862-2293
Email:

River/Waterbody: Tributary of Stony Brook

Lat/Lon: 42.5415, -71.4750

Status: Active

Year Built or Rebuilt: 1930

Owner Classification: Private

Construction Material: Concrete

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
300	3	10.6	8	0.25	42.2	21	51.2	161.2	161.2	

Emergency Spill: N **Drop Inlet: N** **Uncontrolled Spill: Y**

Stoplogs: N **Gate: N** **Pond Drain: N**

National ID#: NH00428

Main Use of Dam: Recreation

Hazard Class: AA

Dam Name: Vijerhof Pond Dam
Dam Code: 007.09
Location: Amherst
Owner: Freestyle Farm LLC
Address: 60 Kendall Hill Road, Mont Vernon, NH 03057
Contact: Ariel Taylor
Phone: 603-672-6124
Email:
River/Waterbody: Tributary of Joe English Brook

Lat/Lon: 42.5439, -71.3755

Status: Active

Year Built or Rebuilt: 1962

Owner Classification: Private

Construction Material: Earth

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
300	4	34	9	0.67	192	56	59	670	670	

Emergency Spill: Y **Drop Inlet: N** **Uncontrolled Spill: N**
Stoplogs: Y **Gate: Y** **Pond Drain: Y**

Type Pipe: CMP

National ID#: NH00485

Main Use of Dam: Recreational

Hazard Class: A

Dam Name: Waterloom Pond Dam
Dam Code: 175.09
Location: New Ipswich
Owner: Alden Engineering Company
Address: 773 Greenville Road, Mason, NH, 03048
Contact: Alden T. Greenwood
Phone: 603-878-2485
Email:

taken July 1982

taken July 1982

River/Waterbody: Souhegan River **Lat/Lon:** 42.4458, -71.5012

Status: Active **Year Built or Rebuilt: 1840**

Owner Classification: Private **Construction Material:** Concrete

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
214		75	22.5	23.1	665	420	32,340	1,950		1,800

Emergency Spill: **Drop Inlet:** N **Uncontrolled Spill:**
Stoplogs: **Gate:** **Pond Drain:**

National ID#: NH00355

Main Use of Dam: Hydroelectric

Hazard Class: A

Photos:

taken 6/10/05


taken 6/10/05

Dam Name: Wheeler Pond Dam
Dam Code: 175.23
Location: New Ipswich
Owner: David or Neil Somero
Address: Wheeler Road, New Ipswich, NH 03071
Contact:
Phone: 603-878-1285
Email:

River/Waterbody: Stark Brook **Lat/Lon:** 42.4522, -71.5305

Status: Ruins

Year Built or Rebuilt:

Owner Classification: Private

Construction Material: Earth/rockwall

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
50		11	5		32.89	10.89				75

Emergency Spill: **Drop Inlet:** **Uncontrolled Spill:**
Stoplogs: **Gate:** **Pond Drain:**

National ID#: NH03497

Main Use of Dam: Recreation

Hazard Class:

Dam Name: Wilton Hydro Dam
Dam Code: 254.02
Location: Wilton
Owner: Gould Leech Trust
Address: PO Box 568, Wilton, NH 03086
Contact: Fred B Roedel
Phone: 603-627-9300
Email:

River/Waterbody: Souhegan River **Lat/Lon:** 42.5026, -71.4411

Status: Active

Year Built or Rebuilt: 1876

Owner Classification: Private

Construction Material: Concrete

Measurements:

Length	Freebrd	Impnd	Height	DrainAr	MaxStor	PermStor	Des Strm	Max Un Disc	Tot Disc Cap	100 yr flow
feet	feet	acres	feet	sq miles	acre-feet	acre-feet	cfs	cfs	cfs	cfs
125		4	17	97	14	14	6360	5420	460	7,550

Emergency Spill: N **Drop Inlet: N** **Uncontrolled Spill: Y**
Stoplogs: N **Gate: Y** **Pond Drain:Y**

National ID#: NH00905

Main Use of Dam: Recreation

Hazard Class: A

Appendix 2

Affected Water Users (AWUs)

User: Amherst Country Club
Address: 72 Ponemah Rd, Amherst, 03031

Reg Number: 20190

Contact: Steve Wilson
Phone: 673-6351
Fax:
Email:

Intake Structure: two 71/2 hp sumps resting 8-10" of bottom of the river

Water Intake: 20190-D01: X coordinate: 999153.375, Y coordinate: 119360.000
20190-S01: X coordinate: 999451.000, Y coordinate: 119967.703

Water Storage: none

Water Use Frequency: Annual use for irrigation, May to October

Average Water Use by month (thousand gallons): 20190-D01 not reporting, 20190-S01 from 2004 NHDES data, yearly avg. = 133.359 tgd

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	0	625	5575.1	7111.9	5112.8	6048.9	64.4	0	0

Days of Water Use: water is used on an as needed basis, typically spring, summer and fall, weather dependent, varying from every day to twice a week

Hours of Water Use: 6 pm to 7 am

Description of Use: to water the golf course, approx. 170 acres

Staffing: Golf course is staffed normal working hours, 5 am to 4 pm weekdays, 5 am to 10 pm weekends

Water Use Measured: meter

Water Use Records: monthly, kept on data sheets

Return Flow/Water reuse: none

Conservation Measures Used: moisture levels are checked daily and water is used only when needed

Stream/River Gage: a stream gage was made to determine local flood stage, also use the stream gage in the Merrimack when taking water samples and checking river levels

Planned shutdowns/changes: none

Other Information:

Water Use Management Possibilities:

Comment: Amherst manages Ponemah as well. Only one withdrawal for both courses, at Amherst.

User: Greenville Water Works
Address: PO Box 343, Greenville, 03048

Reg Number: 20047

Contact: Carla Mary, Woodard and Curran
Phone: 603-878-1338 (to Facility)
Fax:
Email:

Intake Structure:

Water Intake: 20047-S03, X-coord. 939368.625, Y-coord. 108162.297, 20047-S02 not reported since 1993, 20026-S01 not reported since 1999, 20047-D01 not reported

Water Storage:

Average Water Use by month (thousand gallons): from NHDES 2004 data for 20047-S03, yearly average: 113.076 tgd

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3646.1	3219	3696.8	3368.1	1923.3	1922.7	4367.7	4605.1	3802.4	3821.2	3380.4	3633.1

Days of Water Use:

Hours of Water Use:

Description of Use:

Staffing:

Water Use Measured:

Water Use Records:

Return Flow/Water reuse:

Conservation Measures Used:

Stream/River Gage:

Planned shutdowns/changes:

Other Information:
Comment: Pilgrim Foods takes from Greenville rather than separate withdrawal (check this)

User: Greenville Waste Water Treatment Facility
Address: PO Box 343, Greenville, 03048

Reg Number: 20086

Contact: Carla Mary, Woodard and Curran
Phone: 603-878-1338 (to Facility)
Fax:
Email:

Intake Structure:

Water Intake: 20086-D01 X-coord. 946659.875, Y-coord. 99138.977, 20086-S01, labeled as collection system by NHDES, had no data reported for 2004 but a yearly avg of 282 for 2003

Water Storage:

Average Water Use by month (thousand gallons): from NHDES 2004 data for 20086-D01, yearly average: 165.354 tgd

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4617.9	3180.3	4595.8	8063.1	7019.7	4246.6	4424.8	4185.7	4821.2	5005.5	4173.9	6184.9

Days of Water Use:

Hours of Water Use:

Description of Use:

Staffing:

Water Use Measured:

Water Use Records:

Return Flow/Water reuse:

Conservation Measures Used:

Stream/River Gage:

Planned shutdowns/changes:

Other Information:

User: Milford Waste Water Treatment Facility
Address: 1 Union Square, Milford, 03055

Reg Number: 20092

Contact: Larry Anderson
Phone: 603-673-9441
Fax:
Email: Landerson@milford.nh.gov

Milford treatment plant outfall, 6-29-04

Intake Structure:

Water Intake: 20092-D01, X coord: 995352.875, Y coord: 119661.602
20092-S01, no coordinates listed

Water Storage:

Average Water Use by month (thousand gallons): from NHDES 2004 data for 20092-D01, yearly average: 1307.9 tgd

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
40960	31000	41690	69500	47340	36700	31430	31210		32650	32180	44810

*no data reported for Sept, yrly avg for 2003 is 1416.2 with Sept reported

20092-S01, yearly average: 1233.7

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
49080	28990	38530	66090	41060	31960	26360	27090		30990	30870	43500

*no data reported for Sept, yrly avg for 2003 is 1321.8 with Sept reported

Days of Water Use:

Hours of Water Use:

Description of Use:

Staffing:

Water Use Measured:

Water Use Records:

Return Flow/Water reuse:

Conservation Measures Used:

Stream/River Gage:

Planned shutdowns/changes:

Other Information:

User: Milford Fish Hatchery
Address: RR3 Box 364-408, Milford, 03055

Reg Number: 20218

Contact: Robert S. Fawcett
Phone: 603-271-2501
Fax:
Email:

Intake Structure: two gravel packed wells at a depth of approximately 65 to 80 feet

Water Intake: 20218-S01 Well #4 River Well, X coord: 978067.000, Y coord: 126240.102
20218-S02 Well #1 Field Well, X coord: 978886.625, Y coord: 127151.000

Water Storage:

fish hatchery outfall pipe, 6-28-04

Average Water Use by month (thousand gallons): S02, from 2004 NHDES data, avg = 729.694 tgd

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
23436	21924	23436	19440	20088	19440	24552	24552	23760	22520	21600	22320

S01, from 2004 NHDES data,
avg = 1743.18

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
48104	45936	49108	58320	60264	58320	51336	51336	49680	55800	54000	55800

Days of Water Use: every day

Hours of Water Use: all times

Description of Use: well water is pumped to feed the Milford State Fish Hatchery

Staffing: Facility is staffed 24/7

Water Use Measured: meter

Water Use Records: weekly records are kept, a quarterly report is sent to DES

Return Flow/Water reuse: 100% returned, water is pumped to the Head of the Facility then runs through pools, then returned to the river a short distance from where it is pumped

Conservation Measures Used:when the fish population allows, water is shut off from one well, typically late spring/early summer

Stream/River Gage: none

Planned shutdowns/changes: none

Other Information:

Water Use Management Possibilities:

User: Milford Water Works
Address: 1 Union Square, Milford, 03055

Reg Number: 20100

Contact: Larry B. Anderson
Phone: 603-673-9441
Fax:
Email:

Intake Structure: Milford water supply is from 2 gravel packed wells located near the Souhegan River, well #1 700 gpm, well #2 400 gpm

Water Intake: NHDES lists 20100-S01 as Curtis Wells #1 and #2, X coord: 993936.375, Y coord: 121078.203

Water Storage: 1.25 m gallons

Average Water Use by month (thousand gallons): 20100-S01, from NHDES data, 2004, yearly average: 915.143 tgd

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
26331	24103	26111	25398	30086	34527	0	0	0	0	0	0

Days of Water Use: all week

Hours of Water Use: all times

Description of Use: for town water supply

Staffing: Facility is fully staffed M-F

Water Use Measured: meter,

Water Use Records: via SCADA

Return Flow/Water reuse: approx. 90% of withdrawal is returned 5 miles downstream and is measured by partial flume with ultrasonic meter at wastewater facility

Conservation Measures Used:

Stream/River Gage:

Planned shutdowns/changes: plans to add another well to the system

User: Monadnock Mountain Spring
Address: PO Box 518, Mansur Road, Wilton, 03086

Reg Number: 20621

Contact: Vincent Gerbino
Phone: 603-654-2728
Fax:
Email:

Intake Structure: Two adjacent wells

Water Intake: NHDES lists wells as 20621-S01, Mansur Road Spring Well, X coord: 959956.625, Y coord: 118457.000 and
20621-S02, Intervale Road Spring Well, X coord: 958912.313, Y coord: 117547.000

Water Storage: 30,000 gallons


Monadnock wells, 6-28-04

Average Water Use by month (thousand gallons): from NHDES 2004 data, S01 average: 46.968 tgd

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3255	3255	3255	929	929	929	825	825	825	720	720	720

From NHDES 2004 data, S02, average: 46.968

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3255	3255	3255	929	929	929	825	825	825	720	720	720

Days of Water Use: Sunday through Friday

Hours of Water Use: 9 am to 6 pm

Description of Use: Water is bottled for human consumption.

Staffing: Facility is fully staffed M-F with @ 50 people, approx. 10-20 people on Sunday

Water Use Measured: meter, via units produced

Water Use Records: Daily observations have been recorded on data sheets

Return Flow/Water reuse: Water cannot be reused.

Conservation Measures Used: “normal measures”

Stream/River Gage: none

Planned shutdowns/changes: No planned changes

Other Information: no direct draw from river; states “years of data to show that springs are not influenced by surface water”

Water Use Management Possibilities:

User: Pennichuk Water, Amherst Village District Well
Address: 25 Manchester Street
PO Box 1947
Merrimack, NH 03054-1947

Reg Number: 20000

Contact: Donald L. Ware, Senior VP, Operations
Phone: 603-913-2330
Fax: 603-913-2362
Email:

Intake Structure: A gravel packed well, 20000-S01

Water Intake: NHDES well 20000-S01, X coord: 997284.313, Y coord: 130090.000

Water Storage: 225,000 gallons

Average Water Use by month (thousand gallons): from NHDES 2004 data, average: 5.921 tgd

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
253.859	3.63	730	12.99	0	0	0	38.3	0	0	38.89	0

Days of Water Use: Water is used only on an emergency basis.

Hours of Water Use: NA

Description of Use: Water is used on an emergency basis due to water quality issues.

Staffing: Well operation and monitoring performed via SCADA system that is viewed at Pennichuck's Water Treatment Plant in Nashua, NH and monitored 24-7. When the station is running it is checked daily.

Water Use Measured: meter

Water Use Records: Operations are historically trended, daily totals are logged by SCADA system as well as hours and rate of pumping.

Return Flow/Water reuse: Water is not/cannot be reused. All businesses using water from the well system are on septic systems that are within the Souhegan River Watershed.

Conservation Measures Used: annual conservation mailings

Stream/River Gage: none

Planned shutdowns/changes: No planned changes

Other Information: When this well is needed, it is because of a loss of the main supply and as such when it is needed we must be able to turn it on in order to provide continued domestic and fire protection service.

Water Use Management Possibilities:

User: Pennichuk Water, Badger Hill
Address: 25 Manchester Street
PO Box 1947
Merrimack, NH 03054-1947

Reg Number: 20781

Contact: Donald L. Ware, Senior VP, Operations
Phone: 603-913-2330
Fax: 603-913-2305
Email:

Intake Structure: Survey reply lists 3 bedrock wells, NHDES records indicate only 2 from 2004

Water Intake: 20781-S02 and 20781-S03, no water use reported to NHDES for S02 since inception

Water Storage: 80,000 gallons

Average Water Use by month (thousand gallons): 20781-S03, from NHDES 2004 data, yearly average: 12.418 tgd

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	244.5	416.1	546.6	439.8	482.7	585.1	258.6	214.9	226.8

Days of Water Use: Every day

Hours of Water Use: at all times- start and stop times depend on the season, wells run an average of 2.6 hrs during the non-irrigation season and an average of 5.3 hours during the irrigation season

Description of Use: Water is used to meet domestic and fore protection for 106 homes in the Badger Hill subdivision in Milford, NH.

Staffing: Staff visit the well once a week. Critical data on station gathered at station and entered into database at Nashua treatment plant.

Water Use Measured: meter

Water Use Records: weekly records

Return Flow/Water reuse: Water is not/cannot be reused. All homes using water from the well system are on septic systems that are within the Souhegan River Watershed.

Conservation Measures Used: no automatic ingrund sprinklers allowed by subdivision covenants, outside water usage on an odd/even basis.

Stream/River Gage: none

Planned shutdowns/changes: No planned changes

User: Pennichuk Water, Souhegan Woods Well
Address: 25 Manchester Street
PO Box 1947
Merrimack, NH 03054-1947

Reg Number: 20659

Contact: Donald L. Ware, Senior VP, Operations
Phone: 603-913-2330
Fax: 603-913-2362
Email:

Intake Structure: Water is withdrawn from wells adjacent to the Souhegan River. The well is run as required to keep the atmospheric storage tank full.

Water Intake: 20659-S01, listed as GPW 1 and GPW 4, X coord: 1010700.000, Y coord: 122205.203

Water Storage: 50,000 gallons

Average Water Use by month (thousand gallons): from NHDES 2004 data, yearly average: 21.704 tgd

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
666	553	534	711	1903	531	312	268	229	822	653	762

Days of Water Use: Every day

Hours of Water Use: at all times- the well runs an average of 4.9 hrs/day during non-irrigation season and an average of 16.9 hrs/day during the irrigation season.

Description of Use: Water is used to meet domestic and fore protection for 115 homes in the Souhegan Woods subdivision in Amherst, NH.

Staffing: Staff visit the well once a week. Station operations are monitored by a SCADA system that is viewed at Pennichuck's Water Treatment Plant in Nashua, NH.

Water Use Measured: meter

Water Use Records: Historical trends based on 2-minute averages of well production, kept electronically

Return Flow/Water reuse: Water is not/cannot be reused. All homes using water from the well system are on septic systems that are within the Souhegan River Watershed.

Conservation Measures Used: odd/even irrigation, annual conservation mailings

Stream/River Gage: none

Planned shutdowns/changes: No planned changes

User: Peter De Bruyn Kops
Address: 427-3 Amherst Street 341, Nashua, 03063

Reg Number: 20383

Contact: Peter De Bruyn Kops
Phone: 603-881-8821
Fax:
Email:

Intake Structure: removable pipe with foot valve and coarse strainer

Water Intake: 20383-S01, X coord: 1003178.000, Y coord: 118451.898

Water Storage: none

Average Water Use by month (thousand gallons): from NHDES 2003 data, yearly average: 0 tgd

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	0	0	0	0	0	0	0	0	0

Days of Water Use: potentially every day, fall and summer

Hours of Water Use: during dry periods, generally during daylight hours

Description of Use: agriculture-crop irrigation and occasionally frost prevention

Staffing: farmer lives on the farm full time

Water Use Measured: time X # sprinklers X flow rate per sprinkler

Water Use Records: historical records are NHDES quarterly water reports, kept on data sheets

Return Flow/Water reuse: none directly returned, irrigation water may recharge groundwater, no reuse

Conservation Measures Used: experimented with plastic landscape fabric, aware of polymers that hold water and are intended to be mixed with the soil, they are expensive and fears unintended consequences of using them on a flood plain land, tough to remove once incorporated

Stream/River Gage: none

Planned shutdowns/changes: agriculture is entrepreneurial, plans change as crops change based on weather and customers

Other Information: rule of thumb is crops need about 1 inch of water per week, looking for predictable water supply, support for business flexibility, and low capital costs

User: Pike Industries/Wilton Quarry
Address: 3 Eastgate Park Road, Belmont, NH 03220

Reg Number: 20281

Contact: Lawrence R. Major, Jr., NH EHS Manager Region 1
Phone: 603-527-5182
Fax: 603-527-5101
Email: lmajor@pikeindustries.com

Intake Structure: 8" intake 2 feet below the water surface

Water Intake: 20281-S01, X coord: 955803.125, Y coord: 134052.500

Water Storage: 1.5 million gallons

Average Water Use by month (thousand gallons): from NHDES 2004 data, yearly average: 65.39 tgd

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	0	1346.1	1575	3024	2403	2434.5	2286	2430	522

Days of Water Use: every day, most often during weekdays but sometimes on Saturday during periods of high demand for our products

Hours of Water Use: 7 amto 5 pm

Description of Use: water from Stoney Brook is used to wash construction grade aggregates and for dust suppression

Staffing: M-F day shifts, also occasionally on Saturdays

Water Use Measured: pump run time

Water Use Records: daily inspections are conducted for safety and operational purposes, reports to NHDES on a quarterly basis, information kept on data sheets

Return Flow/Water reuse: no direct returns to the river, some water may infiltrate our setting ponds and ultimately contribute to the Stoney Brook through groundwater, some water reused

Conservation Measures Used: low volume spray nozzles, wash water is recycled, stormwater is captured for dust control on quarry roads

Stream/River Gage: Pike does not have a stream gage. Have heard that there is one upstream of quarry on Stoney Brook.

Planned shutdowns/changes: Pike Industries Inc. reduced water use druing the drought of '02 and have maintained that minimal use since. Minimal opportunities for further restrictions.

Other Information: a seasonal business operating from April to December generally, market forces typically create highest demand during the least rainy months, businesses that rely on products are paving contractors, septic installers, concrete manufacturers, building contractors

User: Ponemah Green Golf Course
Address: 54 Ponemah Rd, Amherst, 03031

Reg Number: 20624

Contact: Steve Wilson
Phone: 673-8259
Fax:
Email:

Intake Structure:

Water Intake: 20624-D01, X coord. 999153.375, Y coord. 119360.000 and 20624-S01, X coord. 999451.000, Y coord. 119967.703

Water Storage: none

Water Use Frequency: Annual use for irrigation, May to October

Average Water Use by month (thousand gallons): from 2004 NHDES data, 20624-D01 not reporting, 20624-S01 yearly avg. = This is the same withdrawal as Amherst CC See Amherst for data

Days of Water Use: water is used on an as needed basis, typically spring, summer and fall, weather dependent, varying from every day to twice a week

Hours of Water Use: 6 pm to 7 am

Description of Use: to water the golf course, approximately 20 acres

Staffing: Golf course is staffed normal working hours, 5 am to 4 pm weekdays, 5 am to 10 pm weekends

Water Use Measured: meter

Water Use Records: monthly, kept on data sheets

Return Flow/Water reuse: none

Conservation Measures Used: moisture levels are checked daily and water is used only when needed

Stream/River Gage: a stream gage was made to determine local flood stage, also use the stream gage in the Merrimack when taking water samples and checking river levels

Planned shutdowns/changes: none

User: Souhegan Woods Golf Club
Address: 65 Thorntons Ferry Road II, Amherst, 03031

Reg Number: 20523

Contact: Ryan Lane
Phone: 424-0910
Fax:
Email:

Intake Structure:

Water Intake: 20523-D01, groundwater well, Lat/Lon: 425037, 713422
20523-S01, surface water well taken from Souhegan River, Lat/Lon: 425005, 713354

Water Storage: none

Water Use Frequency: Annual use for golf course irrigation, April to October

Average Water Use by month (thousand gallons): 20523-S01 from 2004 NHDES data, avg.daily use = 61.126, adj. avg. daily use = 104.542

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	2143	3447	6147	2125	4917	2064	1529	0	0

Days of Water Use: water is used on an as needed basis, typically spring, summer and fall, weather dependent, varying from every day to twice a week

Hours of Water Use:

Description of Use:

Staffing:

Water Use Measured:

Water Use Records:

Return Flow/Water reuse: none

Conservation Measures Used:

Stream/River Gage:

Planned shutdowns/changes: none

Other Information:

Water Use Management Possibilities:

Comment:

User: Wilton Water Works
Address: PO Box 83, Wilton, NH

Reg Number: 20065

Contact: Charles McGettigan Jr. Water Commissioner
Phone: 603-654-6602
Fax:
Email:

Intake Structure: two wells

Water Intake: 20065-S01, Everett Well, X coord: 956674.125, Y coord: 115524.898
20065-S02, Abbott Well, X coord: 957345.188, 115827.797

Water Storage: 616,000 gallons in one tank

Average Water Use by month (thousand gallons): from NHDES 2004 data,
S01 yearly average: 100.85 tgd

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3264	2663	2746	2645	3091	3476	2703	0	0	443	6345	3381

S02 yearly average: 123.841

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2884	2449	2672	2761	3262	3494	4087	5828	6076	5496	0	2552

Days of Water Use: every day

Hours of Water Use: 24/7

Description of Use: WWW uses about 250,000 gallons of water for Wilton customers

Staffing: part time employees that tend to the system

Water Use Measured: meter

Water Use Records: daily since July 13, 1988, kept on data sheets

Return Flow/Water reuse: only when there are breaks in the system or when flush hydrants

Conservation Measures Used: every customer is metered

Stream/River Gage:

Planned shutdowns/changes: none.

User: Wilton Waste Water Treatment Facility
Address: PO Box 83, Wilton, 03086

Reg Number: 20426

Contact: Charles McGettigan Jr. Sewer Commissioner
Phone: 603-654-6602
Fax:
Email:

Intake Structure:

Water Intake: 20426-S01, no location listed and no water used, just a transfer line, no data reported to NHDES, 20426 also listed as using well 20092-D01 (Town of Milford), X coord: 995352.875, Y coord: 119661.602

Water Storage:

Average Water Use by month (thousand gallons): from NHDES 2004 data for 20092-D01, yearly average: 152.364 tgd

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4962.4	2894.1	3604	7848.6	6404.6	4847.4	2643.8	4232.8	4139.1	4831.5	3582	5575

Days of Water Use:

Hours of Water Use:

Description of Use:

Staffing:

Water Use Measured:

Water Use Records:

Return Flow/Water reuse:

Conservation Measures Used:

Stream/River Gage:

Planned shutdowns/changes:

Other Information:

Appendix 3

Concurrent Flows and Hydrograph Simulations

3.1 Hydrology

Daily streamflow data for the Souhegan River are available from the United States Geological Survey (USGS). One streamflow gage is located in the lower Souhegan before the confluence with the Merrimack River. A second gage is located in Stony Brook. The Milford precipitation gage provided daily precipitation values from 1944 to 2004. Table 1 describes stations characteristics.

Table 1: Available streamflow and precipitation data

Station Number	Station Name	Latitude	Longitude	Drainage Area (mi^2)	Period of Record
USGS 01094000	Souhegan River at Merrimack, NH	42°51′27′′	71°30′24′′ W	171.3	7/13/1909-9/30/1976 and 10/1/2001 to 9/30/2004
USGS 01093800	Stony Brook Tributary near Temple, NH	42°51′36′′	71°50′00′′ W	3.6	10/1/1927-9/30/2004
COOP 275412	Milford	42.49	71°23′24′′ W	N/A	10/1/1994 to 9/30/2004t

The Souhegan River gaging station was inactive from Water Year 1977 to 2001. For this research, the nearby Stony Brook gage was used to estimate Souhegan flows for the missing time period. The two estimation approaches considered were regression and regional statistical analysis (Maidment, 1993). Both approaches were developed and test using data from periods during which both the Stony Brook and the Souhegan gages were operational (5/1/1963 to 9/30/1976 and 10/1/2001 to 9/30/2004). Relationships were developed between the Souhegan gage and the Stony Brook gage for the first overlap period from (1963 to 1976) and tested using the second overlap period (2002 to 2004).

While both methods provided reasonable estimates, the regression relationships provided better estimates of average daily flow and therefore are used to estimate the missing period. A power equation of the form, $Q_{souhegan} = a\ Q_{stony}^{b}$ where Q is in cfsm, provided the best fit (Table 2). The first regression relationship addressed all flows. The second addressed low flows (< 1 cfsm). The two regression relationships yield identical flow predictions at 1 cfsm. The Stony Brook streamflow data were applied using these regression relationships to estimate flow in the Souhegan River for the missing time period.

Table 2. Regression relationships to estimate Souhegan River streamflow from Stony Brook measured streamflow.

Flow Range	a	b	r^2
All	0.9955	0.8292	0.76
< 1 cfsm	0.9057	0.7807	0.88

3.2 Trend Analysis

The study included a time trend analysis using average discharge, precipitation, and watershed yield (the ratio of precipitation to discharge), and Indicators of Hydrologic Alteration (Richter et al., 1996). Richter et al.'s (1996) *Indicators of Hydrologic Alteration* (IHA) characterize trends in streamflow variability with respect to timing, duration, frequency, and rate of change. IHA statistics were calculated using two periods; water years 1910 to 1976 and water years 1910 to 2004. Linear regression analyses were used to identify trends. Linear regression is a parametric test that quantitatively identifies the presence of a trend. Linear regression of the statistics was used to determine the best-fit line ($y_{fit} = mx + b$) through the data. The slope (m) was used to determine the t_{stat} by

$$t_{stat} = \frac{m}{SE} \tag{1}$$

where the SE is the standard error calculated by

$$SE = \frac{\sqrt{\dfrac{\sum_{i=1}^{N}(y_{fit}(i) - \overline{y})^2}{N-2}}}{\sqrt{\sum_{i=1}^{N}(x(i) - \overline{x})^2}} \tag{2}$$

where N is the number of years, $y_{fit}(i)$ are the values generated from fitted line, $\overline{y}$ is the mean value of the original statistic series, $\overline{x}$ is the average of $x(i)$. A trend is present if the slope of the fitted line is significantly different from zero. A decreasing trend would correspond to a negative slope, while an increasing trend would correspond to a positive slope. Significant trends were identified, using a 95% significance level ($\alpha = 0.05$). Trend results of the flow statistics for each gage are shown in Table 3.

Note: the IHA method calculates 67 different statistics. With the task of testing many paired comparisons there is usually the need to make the effective contrast on a single more conservative comparison. Assuming independent comparisons, the experiment-wise error rate (i.e., the probability of false rejection of at least one of the hypotheses) is given by $\alpha=1-(1-\alpha_p)^r$, where α_p is the selected probability of type I error for a specific comparison and r is the number of comparisons. That is, to accomplish a

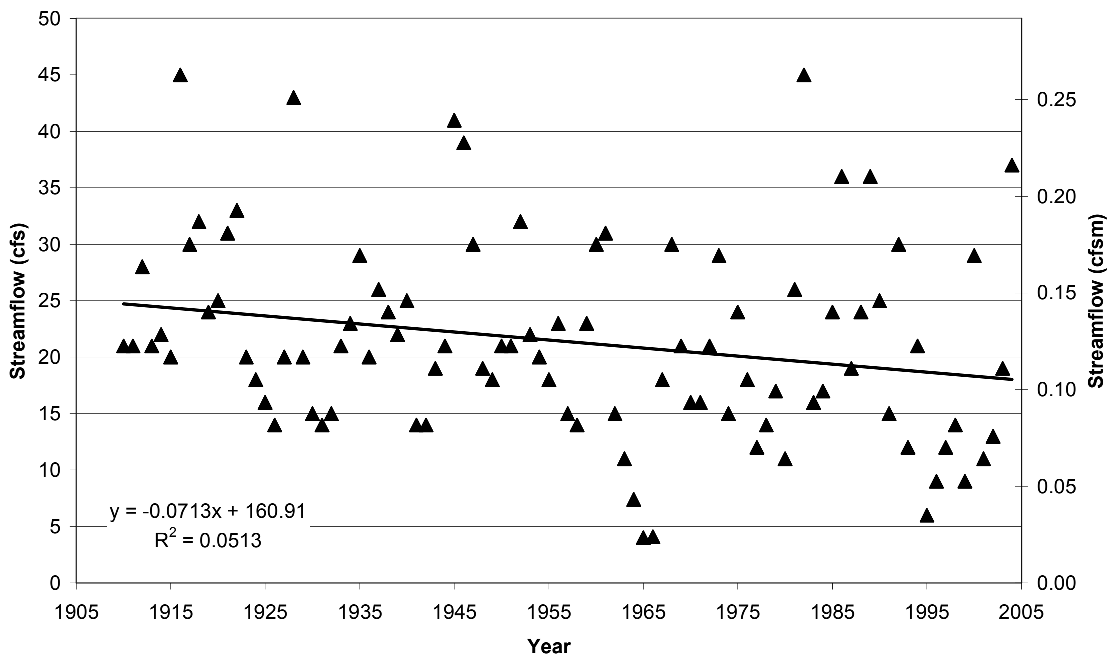
95% significance level for the entire series of tests, each individual test should have 99.92% significance level ($\alpha = 0.000765$).

Table 3 summarizes the trend results. Only IHA statistics having significant trends are shown. The results show no significant trends for annual discharge, precipitation, or yield ratio. Significant decreases in the annual 1 and 3-day minimum values (Figure 1) and the number of reversals (switch from increasing flow to decreasing flow or vice-versa) were found. A trend analysis for the period from 1977 to 2004, showed the magnitude slope for the 1 and 3-day minimum values in the Souhegan river, but no trend was found for Stony Brook during the same period. The day of the year having the 1-day minimum value was consistently within a 3 month period (July 14th to October 17th) and did not change throughout the study period.

Table 3. Trends analysis results

Statistic	Analysis Period (WY)	Significant. Trend	Slope	Slope p-value	r^2
Average Annual Streamflow	1910-2004	No	0.0335	0.903	0.000
Average Annual Precipitation	1952-2004	No	0.0140	0.821	0.001
Basin Yield (Q/P)	1952-2004	No	-0.0008	0.472	0.010
1-Day Min	1910-2004	Yes	-0.0761	0.027	0.051
3-Day Min	1910-2004	Yes	-0.0761	0.040	0.045
Reversal	1910-2004	Yes	-0.3516	0.000	0.310

1-Day Minimum Flow



7-Day Minimum Flow

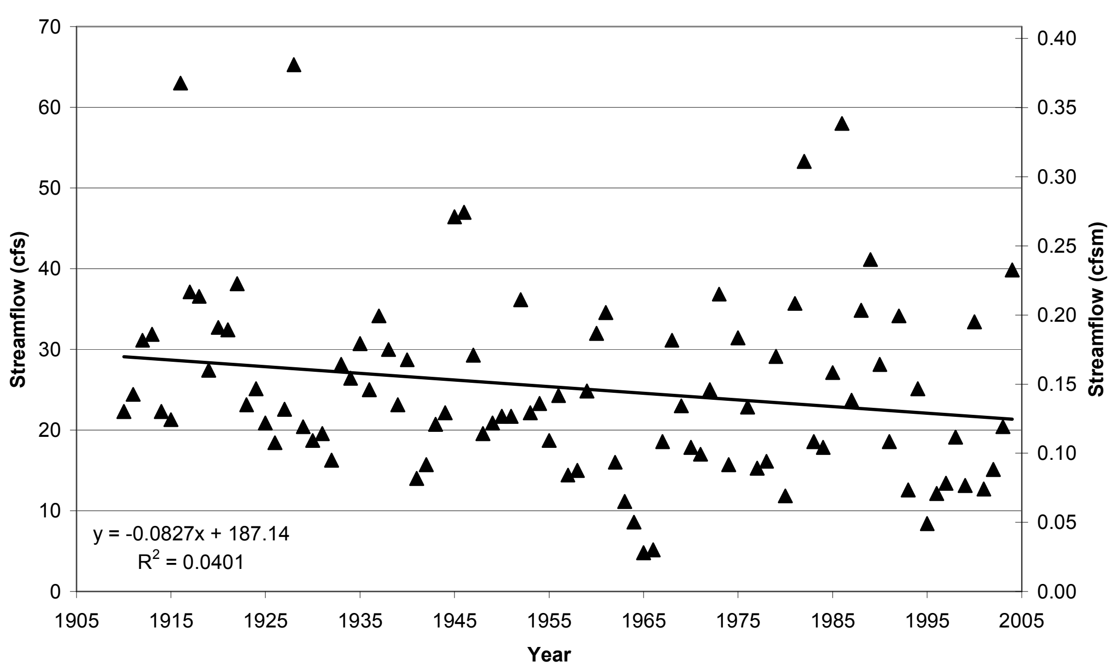


Figure 1. 1 and 7-day annual minimum streamflow values for the Souhegan River from 1910 to 2004. Annual minimum values were determined using the water year.

3.3 Concurrent Flow Analysis

Concurrent flow measurements were conducted over a range of flows at 10 locations upstream of the USGS gage. Watershed area for each location was determined using ArcGIS. Measured flows were scaled by watershed area to determine flow values in cfsm. These measurements were used to develop regression relationships between the gage data and the flow at each location where $y_{fit} = mx + b$ where m and b are the slope and intercept of the regression relationship, respectively. The relationships will be used to estimate streamflow at the upstream locations. Table 4 summarizes the locations and regression analysis. A result where $m=1$ and $b=0$ would indicate that scaling USGS streamflow data by the watershed area alone is the best relationship. The results indicate that the lower Souhegan is fairly well represented by an area weighting approach, but the Souhegan flow upstream of Milford follows a different relationship.

3.4 Streamflow Time Series

The streamflow record from water years 1910 to 2004 was used to identify 3 year periods having wet, dry, and average conditions. In addition, streamflow values for the last five years and a 30-yr period were identified. 3-yr average streamflow values were determined using a 3-yr moving window. When available, the annual precipitation record was examined to support the selection of 3-yr periods. The maximum average flow (376.0 cfs) occurred from 1951 to 1953 and had a correspondingly high precipitation value of 48.4 in. The minimum average flow (154.4 cfs) occurred from 1964 to 1966 and was preceded by the lowest average annual precipitation (31.8 in) from 1963 to 1965. Average conditions (283.1 cfs) were found from 1994 to 1996. Similar average streamflow also occurred from 1945-1947 (284.8 cfs). The latter will be used as the

Table 4. Concurrent flow results for locations upstream of the Souhegan River USGS gage using the relationship $Q_{upstream,\, cfsm} = a\,.Q_{USGS,\, cfsm}{}^{b}$

Site	Description	Area (mi^2)	Ratio to USGS gage	Num. of Measures	a	b	R^2
SR6	Handicap Access Fish Ramp - Greenville	33.9	0.198	4	0.6078	0.7774	0.962
SR12	High Energy Bank - Greenville	37.0	0.216	4	0.6307	0.7819	0.731
SR6/SR12				8	0.6189	0.7793	0.830
SR16	Upstream of Monadnock Water	64.6	0.377	3	1.0478	1.599	0.995
SR18	Intervale Road - Wilton	65.0	0.379	2	0.8505	1.2962	1.000
SR16/18				5	0.9437	1.4540	0.984
SR25	Wilton wastewater pumping station	102.3	0.597	4	0.5947	1.0369	0.824
SR31	Shopping Center Mall - Milford	127.2	0.743	3	0.964	1.3287	0.991
SR34	Electric Substation - Milford	139.4	0.814	3	1.0151	1.4825	0.984
SR31/34				6	0.996	1.4159	0.981
SR50	Boston Post Road - Amherst	159.0	0.928	3	0.9573	1.3073	0.979
SR56	Tomalison Farm - Amherst	165.6	0.967	3	0.9726	1.3207	0.996
SR50/56				6	0.9649	1.314	0.987
SR62	Turkey Hill Road - Amherst	169.4	0.989	2	0.8233	1.0098	1.000
USGS	USGS Gage	171.3	1.000	N/A	N/A	N/A	N/A

1945 to 1947 data were measured while the 1994 to 1996 data were estimated from the Stony Brook gage data. The average streamflow over the last 5 years (262.8 cfs) was slightly below the long-term average conditions. The selected 30-yr period is 1948 to 1977. This period includes historical wet and dry periods and has an average flow (286.5 cfs) that is close to the long-term average. In addition, as the precipitation record began in 1952, all but four years of the record have daily records of precipitation.

Predevelopment hydrographs were estimated using the results from trend analysis and historical dam operation. Here, two factors are noteworthy. First, the 1 and 3-day minimum flow values have decreased steadily over the study period. Selection of the intermediate period to provide a 30 year record provides and intermediate measure of low flow values. Second, dam operations, through short-term management to increase and decrease storage, have historically influenced streamflow records. For the time series identified above, periods having dam management were determined by comparing streamflow hydrographs to daily precipitation values and identifying periods without rainfall that had anomalous increases or decreases. These periods were modified to provide a continuous hydrograph recession curve using the baseflow recession method. The method relates streamflow at two times using an exponential decay function to predict the baseflow recession as follows: $Q_{t+\Delta t} = Q_t e^{-k\Delta t}$ where Q is the streamflow, k is the baseflow recession constant, and Δ t is the time interval between the two measurements. Streamflow values, one day prior to and one day immediately after the anomalous period, were determined and used to calculate the baseflow recession constant. The streamflow values during the anomalous period were estimated using the baseflow recession equation where Q_o was set to the streamflow on the day prior to the anomalous period. These values replaced the measured values. A total of 30 periods that typically lasted less than one week were modified for the 30 year record.

Appendix 3 References:

Maidment, D. R. 1993. Handbook of Hydrology. United States: McGraw-Hill;

Richter, B. D.; Baumgartner, J. V.; Powell, J., and Braun, D. P. 1996. A method for asseessing hydrologic alteration within ecosystems. Conservation Biology. 10(4):1163-1174.

Appendix 4

Recreation Surveys

RECREATION SURVEY

Date: October 10, 2005

Location: Souhegan River, Route 31 Bridge crossing near Greenville/ Wilton town line.

Number of Individuals: 2

Survey Questions:

1) **How often do you come here?**

   Both: two to three times a year.

2) **Where did you travel from?**

   Lexington, Massachusetts
   Lunenburg, Massachusetts

3) **How do you monitor flow conditions?**

   Both: USGS Merrimack gage. Need to keep funded.

4) **What reaches do you run?**

   Greenville to Wilton.

5) **What is the best flow range to run?**

   1 to 2.5 feet on gage at top. 6 feet at Merrimack borderline too high. 4.7 feet today.

6) **What is the minimum flow you would consider running?**

   1 foot on gage.

7) **Can we contact you for follow-up?**

   Names: Conrad Nuthmann and Tom Todd

   Contact Information: On file

RECREATION SURVEY

Date: October 10, 2005

Location: Souhegan River, Route 31 Bridge crossing near Greenville/ Wilton town line.

Number of Individuals: 3

Survey Questions:

1) **How often do you come here?**

   Two: 3 to 4 times a year.
   One: 1st time in 25 yrs.

2) **Where did you travel from?**

   Hopkinton, New Hampshire.
   Henniker, New Hampshire.
   Bedford, Massachusetts.

3) **How do you monitor flow conditions?**

   USGS Merrimack gage.
   American Whitewater Association web site.

4) **What reaches do you run?**

   Old powerplant to Wilton.

5) **What is the best flow range to run?**

   Today was okay, more is better.

6) **What is the minimum flow you would consider running?**

   Not much less than todays flow.

7) **Can we contact you for follow-up?**

   Names: Jim Sindelar, Bob Pugh and Roger Belsan.

   Contact Information: On file

RECREATION SURVEY

Date: October 10, 2005

Location: Souhegan River, Route 31 Bridge crossing near Greenville/ Wilton town line.

Number of Individuals: 1

Survey Questions:

1) **How often do you come here?**

   2 times a year in the spring.

2) **Where did you travel from?**

   Hillsboro, New Hampshire.

3) **How do you monitor flow conditions?**

   Tough, gage at Stoney Brook (discontinued), Wilton guy checks.

4) **What reaches do you run?**

   Upper part, Greenville to Route 31.

5) **What is the best flow range to run?**

   More than today.

6) **What is the minimum flow you would consider running?**

   Todays flow.

7) **Can we contact you for follow-up?**

   Names: Shannon Valera

   Contact Information: On file

RECREATION SURVEY

Date: October 10, 2005

Location: Souhegan River, Route 31 Bridge crossing near Greenville/ Wilton town line.

Number of Individuals: 1

Survey Questions:

1) **How often do you come here?**

   12 times a year, spring and fall.

2) **Where did you travel from?**

   Fitchburg, Massachusetts

3) **How do you monitor flow conditions?**

   Word of mouth, mup.org.

4) **What reaches do you run?**

   Below dam to Route 31, Route 31 to Wilton.

5) **What is the best flow range to run?**

   Based on gage at access point. Minimum 700 cfs (USGS Merrimack), ideal 1,200 cfs.

6) **What is the minimum flow you would consider running?**

   700 cfs, Merrimack gage.

7) **Can we contact you for follow-up?**

   Names: Pat Wyman

   Contact Information: On file